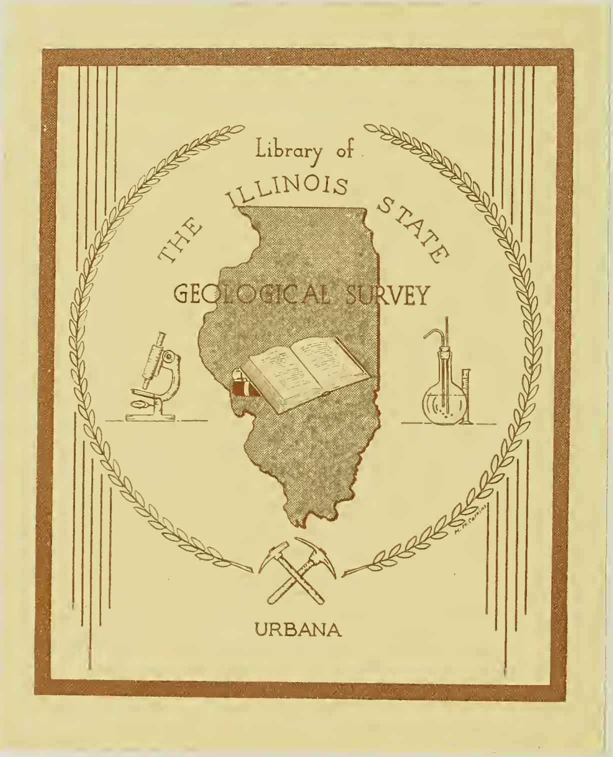

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
A. M. SHELTON, *Director*

DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*

BULLETIN NO. 53

GEOLOGY AND ECONOMIC RESOURCES OF THE ST. PETER SANDSTONE OF ILLINOIS

BY

J. E. LAMAR

AUG. 26TH 1818

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
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GEOLOGY AND ECONOMIC RESOURCES OF THE ST. PETER SANDSTONE OF ILLINOIS

By J. E. Lamar

CHAPTER I—INTRODUCTION

General Statement

The silica sand industry of Illinois is one not only of great state importance but also of national importance. Illinois ranks first in the production and value of glass sand, which it ships to many parts of the United States; in 1925 over 34 per cent of the sand sold in the country for the manufacture of glass was produced from the St. Peter formation of the State. In the same year, 26 per cent of the country's production of ground sand or sandstone came from the St. Peter of Illinois as well as a large per cent (no actual figure is available) of the steel molding sand produced in the United States. Perhaps the most widely used and known product of Illinois silica sand industry is the Ottawa Standard Testing sand. Although the actual tonnage of this type of sand produced is small, it is standard throughout the United States and in some foreign countries for testing cements and for other testing purposes when a very uniform, even textured sand is desired. The division according to uses of the total production of St. Peter sand in Illinois for 1925 is shown in figure 1.

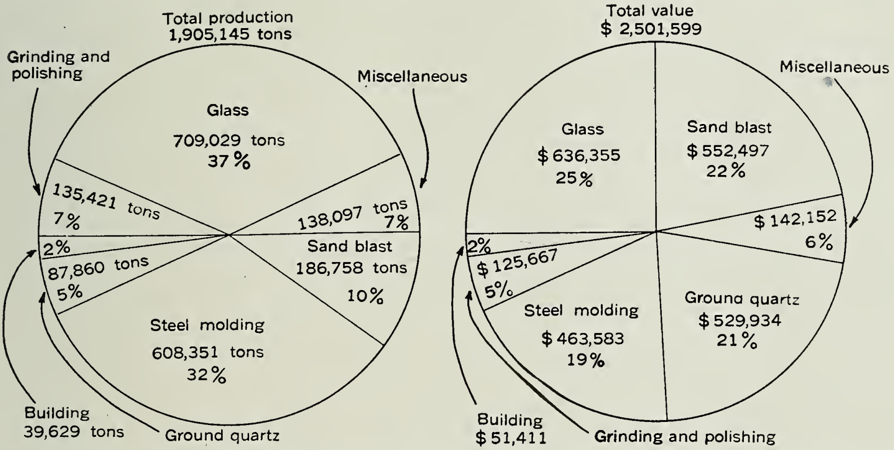

Fig. 1. Graph showing the amounts and values of the various grades of St. Peter sand produced in Illinois in 1925.

Since early in the nineteenth century and possibly before, the St. Peter sandstone of Illinois has been known as a high silica sand. Its earliest known uses as a high silica sand were for molding and for bottle and window glass. With the demand of late years for sands of a given sieve analysis and purity, the industry has developed into one of the important mineral industries of Illinois. In pre-railroad days, commercial development of the sandstone in the bluffs and rock terraces of Illinois and Fox rivers and along the Illinois and Michigan Canal in the vicinity of Ottawa and Utica was feasible because of favorable quarrying conditions and easily accessible water transportation. In the present era of railroad transportation, the Chicago, Rock Island and Pacific Railway and the Chicago, Burlington and Quincy Railroad, following the valleys of the same streams respectively, afford modern shipping facilities to the St. Peter sand industry.

The future of the Illinois silica sand industry has its problems and its encouragements. The producers of crude sand are generally being forced to more systematic and up-to-date methods of stripping, as the quarries are worked back into territory with thicker overburden. The prevalent low price for crude sand has necessitated more economical and modern loading methods. Quantity production essentially has made continued operation possible. The further success of the silica sand industry as a whole is probably dependent on unification of effort, and cooperation towards the elimination of wasteful competition. Without doubt the completion of the Lakes to Gulf deep waterway will stimulate greater production because of anticipated lower freight rates on bulk shipments of sand to Great Lakes and Mississippi River markets.

USE OF TERMS "SAND" AND "SANDSTONE"

There is no little confusion in the literature on the St. Peter formation regarding the use of the terms "sand" and "sandstone." It has seemed advisable, therefore, to define these terms as used in this report. By St. Peter sand is meant the unconsolidated product resulting from the disintegration, either natural or artificial, of the St. Peter sandstone. The term sandstone is used to describe the formation as it occurs in the natural, undisintegrated state.

PURPOSE OF REPORT

In view of the local and national importance of the St. Peter sandstone of Illinois, the study of the formation was undertaken in the summer of 1925 to obtain detailed data concerning it and to further a better understanding of the character and details of the sandstone and the industry dependent upon it, both from the economic and from the scientific standpoint.

ACKNOWLEDGMENTS

In the field and office work incident to this report the cooperation of the St. Peter sandstone operators has always been most willing and helpful; the author wishes to express his sincere appreciation to these men. Acknowledgment is made of the valuable services of Mr. H. G. Martin who assisted in the field work and of Mr. C. R. Clark who helped in testing the sand samples. The geological reports on the Oregon, Dixon, Ottawa-Marseilles, and La Salle-Hennepin quadrangles by Messrs. A. Bevan, R. S. Knappen, L. W. Currier, and G. H. Cady respectively, have been freely referred to during the preparation of this report and acknowledgment is made of the valuable information obtained from the bulletins and unpublished manuscripts. The constructive criticism of the manuscript by Professor C. W. Parmelee of the Department of Ceramic Engineering of the University of Illinois, is also gratefully acknowledged. To Dr. M. M. Leighton, Chief of the Illinois Geological Survey, the author wishes to express thanks for his valuable criticisms of the work and generous administration of affairs pertaining to the investigation.

CHAPTER II—THE GEOLOGY OF THE ST. PETER SANDSTONE

Name

The St. Peter sandstone was named by Owen[1] in 1847 from exposures near St. Paul, Minnesota, along the present Minnesota River formerly known as St. Peter River.[2]

Distribution

The distribution of the outcrops of the St. Peter sandstone in the United States and the approximate area underlain by this formation are indicated in figure 2. It is to be noted that the sandstone is found principally in the area drained by the Mississippi and its tributaries.

In many places throughout Illinois, the St. Peter is penetrated by deep wells and doubtless underlies all of the State with the exception of local areas where it has been removed by erosion. However, the sandstone outcrops in comparatively few places which may be grouped into four principal areas (Pl. I); these are, in the order of importance, the Ottawa-Utica area, including the outcrops along Illinois River west of Ottawa for about 8 miles and on Fox River from Ottawa north to Millington about 25 miles, the Oregon-Dixon area, the Brookville-Harper area, and the Calhoun County area.

In the Ottawa-Utica area the sandstone is exposed in rock terraces in Illinois River Valley for a distance of about 3 miles from Ottawa to Twin Bluffs, in the vicinity of Ottawa, and north from the city in the rock terraces along Fox River. Locally the sandstone forms a bluff in the vicinity of Wedron on the Fox. The outcrops are in general relatively free from iron compounds and are part of the upper portion of the St. Peter formation. The covering on the rock terraces is thin—in most places its thickness varies from 6 inches to about 10 feet—and consists of river alluvium, glacial gravel and glacial drift. Locally a thin capping of Platteville-Galena limestone is present. Because the sandstone is free from iron and because the overburden is relatively thin, these rock terraces are the sites of most of the quarries producing washed sand.

From Twin Bluffs west to Utica, the St. Peter rises in the north bluff of Illinois River. For about 4 miles west from Twin Bluffs, the bluff is capped with clay and coal of Pennsylvanian age. (See fig. 3.) This is the area in which the yellowest sand is found. From the western limit of the Pennsylvanian beds west to Utica, a distance of about 2 miles, the sandstone

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[1] Owen, D. D., Sen. Exec. Doc., No. 2, 30th Cong., 1st sess., p. 169, 1847.

[2] Knappen, R. S., Geology and mineral resources of the Dixon quadrangle: Illinois State Geol. Survey Bull. 49, p. 48, 1926.

Outcrop of St. Peter sandstone

Area where St. Peter sandstone immediately underlies the surficial materials or is known to be present at a shallow depth.

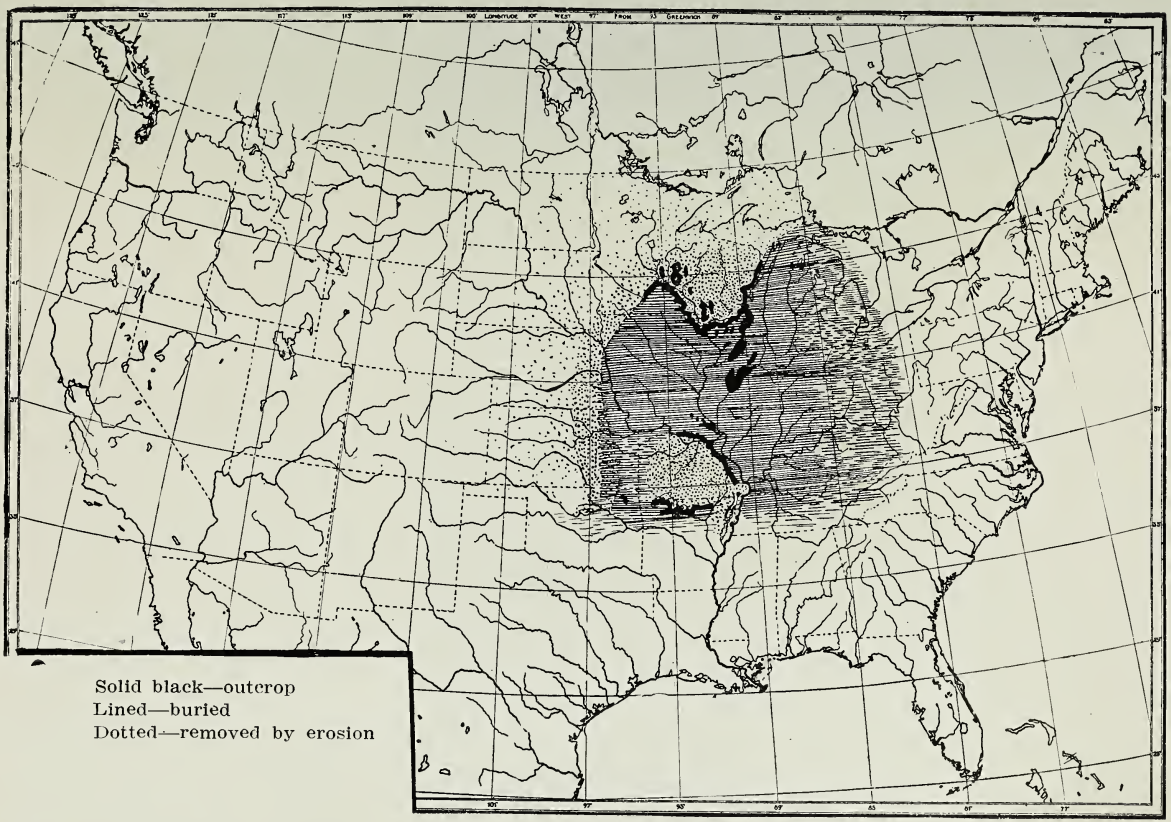

Fig. 2. Map showing the distribution of the St. Peter sandstone in the United States. (From Dake, C. L., The problem of the St. Peter sandstone: Univ. of Missouri School of Mines and Metallurgy Bull., technical series, vol. 6, No. 1, pl. III, August, 1921.)

is somewhat less yellow. Glacial drift caps the sandstone. West of Utica the sandstone is not present in the river bluff along the crest of the La Salle anticline for a distance of about 1¼ miles. In the vicinity of Pecumsaugan Creek, however, the sandstone appears again in the upper part of the bluff and at Split Rock dips sharply to the west beneath Pennsylvanian beds. Outcrops of the St. Peter are found in most of the tributary valleys in the north bluff of Illinois River; also at intervals along Little Vermilion River from Troy Grove south to sec. 27, T. 34 N., R. 1 E.; along the lower 4 miles of Tomahawk Creek and along the tributaries of Little Vermilion River in sec. 2, T. 33 N., R. 1 E.

In the south bank of Illinois River the St. Peter forms bluffs and outcrops in the valleys incident to the bluffs from Ottawa to Little Rock about 2½ miles southwest of Utica. The overlying formations are principally Pennsylvanian beds though locally, as at the edge of the bluff in Starved Rock State Park and near Little Rock, the sandstone is bare or is covered with a thin mantle of soil or glacial till.

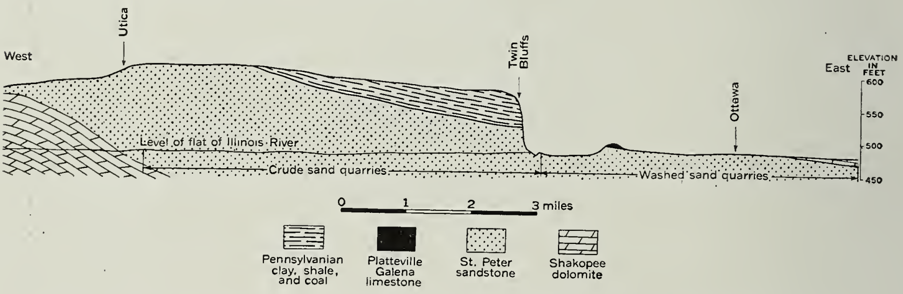

Fig. 3. Generalized sketch of the north bluff of Illinois River showing the position of the St. Peter sandstone and the overlying and underlying beds.

Buffalo Rock, standing alone in the flood-plain of the Illinois, is an erosion remnant of St. Peter sandstone capped by Pennsylvanian beds. It was probably once a part of the north bluff of the river. The sandstone is principally the yellow type sold for steel molding.

Another limited outcrop of St. Peter occurs at Deer Park about a mile and a half east of Oglesby, where the sandstone forms cliffs and canyons.

About a mile northeast of Millington in Kendall County, erosion of a low arch in the rock strata has exposed the St. Peter in the banks of Fox River at intervals for a distance of one or two miles. The quarry of the Ballou White Sand Company is located in this outcrop. The sand is principally white or light yellow.

In the Oregon-Dixon area in Lee and Ogle counties the St. Peter forms the steep slopes and bluffs of the northwest valley wall of Rock River. In the region immediately south of Oregon the bluff is very precipitous. Castle Rock is an isolated rock hill composed of St. Peter sandstone (fig. 4). Aside from its scenic beauty, Castle Rock is of interest because it shows the bedded and locally cross-bedded character of the St. Peter and is a typical example of the better exposures. Away from the river, the sandstone outcrops along many creeks and underlies a broad band of country which is about 2 miles wide in the vicinity of Oregon. It is in this area of outcrop that the quarry of the National Silica Company is located.

On the southeast side of Rock River the sandstone outcrops from Daysville south of Franklin Creek but forms conspicuous bluffs only in secs. 29 and 31, T. 23 N., R. 10 E. The sandstone underlies the region between Clear and Franklin creeks and also outcrops in the southwest bank of Franklin Creek to sec. 2, T. 21 N., R. 10 E. There are also scattered outcrops south of Grand Detour, in the vicinity of Franklin Grove, and along Pine Creek in secs. 15, 22, 23, and 27, T. 23 N., R. 9 E.

Fig. 4. Outcrop of St. Peter sandstone at Castle Rock in the northwest bank of Rock River near Oregon, Ogle County.

Northwest of Oregon about three quarters of a mile, the St. Peter forms the upper slopes of a prominent ridge. There are also scattered outcrops in the vicinity and in secs. 5, 6, and 8, T. 23 N., R. 11 E. In the outcrops of the Oregon-Dixon region the St. Peter is overlain either by glacial drift alone or by the Glenwood and Platteville formations together with glacial drift.

North of Leaf River in the S. ½ sec. 25, the SE. ¼ sec. 23 and the N. ¾ sec. 24, T. 25 N., R. 9 E., there are a few outcrops of St. Peter sandstone overlain by Platteville-Galena limestone.

In northwest Ogle County between Harper and Brookville the St. Peter outcrops along some of the streams and in some hill tops. The sandstone is in general yellow, and is commonly overlain by glacial drift.

A small outcrop of upper St. Peter occurs in Winnebago County northwest of Shirland in sec. 32, T. 29 N., R. 11 E., along Sugar River. In the center of the NE. ¼ of the section, 8 or 10 feet of green sand is exposed overlain by Platteville limestone. About half a mile southwest in the opposite bank of the river about 15 feet of medium-bedded calcareous sandstone, probably St. Peter, is exposed.

In Calhoun County the St. Peter forms a precipitous bluff along Mississippi River from Dogtown Landing in the SW. corner sec. 29, T. 12 S., R. 2 W., north for about a mile. The outcrop is the result of deformation of the rock strata along the Cap-au-Gres fault which extends E. 5° S. through Dogtown Landing. The St. Peter outcrops on the upthrow, or north side of the fault. In general the sandstone is more firmly cemented than the St. Peter in the Ottawa district and contains nodules and bands of calcarerous sandstone, particularly in the upper portion of the exposure. It seems likely that this calcarerous material has been introduced into the sandstone by water percolating downward from the overlying limestones. The sandstone contains numerous concretion-like structures of sand which have a maximum diameter of eight inches and resemble large oolite grains. Some have five rings of green and pink mottled sand. Locally the sand contains a considerable amount of iron oxide, which occurs principally as bands roughly paralleling the bedding. The sand in the weathered portions of the outcrop commonly show secondary additions to the grains. Numerous small ripple marks are present.

Lithology

GENERAL LITHOLOGIC CHARACTER

Perhaps the outsanding lithologic features of the St. Peter, and the ones for which it is best known are the purity, homogeneity, roundness of the sand grains, and saccharoidal character of the sandstone. In Illinois at least the rounded sand grains are principally the larger grains. It is of interest that the rounding of the grains of the older, New Richmond sandstone, outcropping along Franklin Creek near the town of Franklin Grove in Lee County, is not notably different from that of the St. Peter sand grains; yet the younger sandstone is probably more persistent and extensive laterally, and is commonly more easily identifiable because it is the first sandstone of any consequence with rounded grains encountered in wells drilled in Illinois.

In general the Illinois St. Peter is a thick-bedded deposit but the bedding is not as distinct as in other sandstones because of the homogeneity and purity of the formation.

Despite its loosely cemented character, the St. Peter withstands the effects of weathering well in natural exposures. Where it is not subject to rapid erosion, it is commonly brown and is case hardened to such an extent that it is sometimes difficult to break into the unweathered portion with a hammer. This case hardening seems to have developed most in places where the sandstone is generally moist. Where the sandstone is subject to severe weathering it is usually locally soft and loose. The color of the sandstone depends principally on its iron content. Many exposures are banded horizontally with yellow beds of iron-stained sand and have also vertical or nearly vertical, ramifying, vein-like zones colored by yellow iron oxides. In other places where the iron content is lower the sand is buff, gray or white.

THE LITHOLOGY OF THE BASAL ST. PETER SEDIMENTS AND ASSOCIATED BEDS

A study of churn-drill records, largely without samples, indicates that the basal St. Peter sediments deposited on the irregular surface of the Prairie du Chien series, are varied, and that the depth of the basins of sedimentation has had no striking effect on the type of sediments deposited in them. In other words, the basal St. Peter sediments do not possess consistent characteristics typical of, or apparently related to, their topographic position on the irregular surface of the Prairie du Chien.

The most common rock reported immediately below the St. Peter is the Shakopee limestone or dolomite of the Prairie du Chien series. Some alternations of comparatively thin beds of dolomite or limestone and sandstone or sandy dolomite are reported. It is probable that these beds also belong to the Shakopee, rather than to the St. Peter, as is the case in the Utica-La Salle region where the exposed Shakopee contains beds of calcareous or dolomitic sandstone which might readily be reported in drill records as sandstone or sandy dolomite or limestone. Cady[3] gives the following section of the Shakopee compiled from well records in the La Salle Region:

Section of Shakopee formation in La Salle area	Thickness Feet
Dolomite, light brownish gray; shale, gray	12
Sandstone, colorless, coarse	4
Dolomite, light brown; shale; limestone	38
Sandstone	5
Dolomite, gray, semi-crystalline	4
Dolomite, gray, slightly calcareous	25
Dolomite, brownish	8
Dolomite, white, calcareous	37
Dolomite, white; shale, gray; sandstone	5
Dolomite, white, calcareous, flinty	6
Dolomite, white, calcareous	24
Dolomite, brown to buff	18
Dolomite and sandstone	4
	190

The sand noted in the Shakopee at the outcrop was rounded and resembled greatly the sand from the St. Peter or New Richmond sandstones. The formation also contains locally beds of siliceous oolite, which might be called sand by those unacquainted with oolite.

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[3] Cady, G. H., Geology and mineral resources of the Hennepin and La Salle quadrangles: Illinois State Geol. Survey Bull. 37, p. 32, 1919.

In numerous well records shale is reported between the beds which are strictly Shakopee and those which are definitely St. Peter, but it was not seen in outcrop. It is commonly reported as red, shaly marl, or red marl shale, or as green, blue or gray shale. In the Joliet region a maximum of 60 feet of red shale is recorded, also 25 feet of micaceous green shale, and 15 feet of blue clay. At Dwight in Livingston County the St. Peter is underlain by 10 feet of green shale; at Zion City in Lake County by 20 feet of red shale marl; at North Chicago in the same county by 50 feet of shale, gray, with red spots in the upper portion and red with green spots and mottled chert pebbles in the lower portion; and at Area (Mundelein) in Lake County green shale is reported below the sandstone. In McHenry County three wells on one farm near Harvard record 62, 43, and 69 feet of red shale or marl. In Jo Daviess County at Galena red and purple shale are reported; at Kampsville, Calhoun County, 7½ feet of blue shale; at Mt. Carmel cemetery in Cook County 10 feet of green shale; at Rock Island in Rock Island County 5 to 30 feet of red shale; at Amboy in Lee County 10 feet of shale.

The red shale is doubtless a consolidated clay which originated as a residuum from the solution of the Shakopee dolomite at some time during the interval between the deposition of the Shakopee and the beginning of St. Peter deposition. It is possible that the green and blue shales have orginated in the same fashion from limestone containing a smaller amount of iron, or that the green and blue colors are due to a difference in the chemical condition of the iron in these shales as compared with the iron in the red shales. Studies of the probable topographic occurrence of these different colored clays on the pre-St. Peter sub-surface land mass do not indicate any unique topographic position for any specific variety.

Some of these shales lying beneath the St. Peter proper are reported to contain chert fragments which are doubtless residual from a cherty limestone.

The question arises whether these residual clays should be included with the St. Peter or the Shakopee. Inasmuch as they represent rock materials accumulated neither during Shakopee nor during St. Peter time it would seem that they should not be included with either of the two formations but rather be considered as a separate formation. However, as the St. Peter sea encroached upon the region of these residual clays sufficient material of St. Peter age was mixed with the upper portion of the clays so that in general a sharp upper contact is lacking, and the shales have therefore commonly been included with the St. Peter.

One of the frequently reported basal St. Peter sediments is sandstone with chert pebbles. Although this type of chert conglomerate is known in many different parts of the State, it seems best developed in Cook and Lake counties where 30 feet of sandstone with pebbles of chert is commonly reported. In some places green shale is intercalated with the conglomerate.

Chert conglomerate was noted in the base of the St. Peter in outcrop only at the center of the E. ½ NE. ¼ sec. 28, T. 22 N., R. 10 E. The exposure at this place consists of about 5 feet of green sandstone with a 3-inch bed of conglomerate near the base. The conglomerate pebbles consist principally of chert, and their size ranges from that of coarse sand to about that of a pea. One vein-quartz pebble and a number of pebbles of quartzitic sandstone were also noted. The pebbles are all rounded, and the pitted surface of the chert indicates that it underwent a long period of solution. Most of the chert is yellow or white. The matrix of the conglomerate is sand consisting of rounded grains of typical St. Peter character. On the whole it is medium or fine-grained, but locally the conglomerate contains bands of coarse sand.

In view of the presence of the vein-quartz pebble and the rounded sandstone pebbles, it seems likely that there was transportation of coarse material from without the Illinois St. Peter basin, since the Shakopee is not known to contain materials similar to the vein-quartz and sandstone with the siliceous cement.

A very characteristic phase of the basal St. Peter in the La Salle region is oolitic chert as beds and in clay. In the NW. corner sec. 35, T. 34 N., R. 1 E., a blue clay containing oolitic cherts is exposed below the common white St. Peter. A bed of oolitic chert 8 feet thick, resting unconformably on argillaceous limestone, probably the Shakopee, was noted in the creek in the SW. corner NE. ¼ sec. 7, T. 33 N., R. 2 E. The cherty layer also included some sandy and calcareous beds. A similar oolitic chert was noted near Oregon in Lee County in the SE. ¼ sec. 29, T. 23 N., R. 10 E.

Cady[4] gives the following description of the contact of the Shakopee and St. Peter along Pecumsaugan Creek:

Character of strata at the base of the St. Peter sandstone and the top of the Shakopee dolomite along Pecumsaugan Creek

Formation and bed	Thickness		Depth	
	Feet	*In.*	*Feet*	*In.*
St. Peter sandstone:				
Sandstone or sand				
Clay, soft, blue	1		1	
Sandstone with flints	2		3	
Sand, brown to white		9	3	9
Clay, flints and yellow sand	1	6	5	3
Flints and clay, yellow, weathered		4	5	7
Sandstone, flinty		1	5	8
Clay, blue, oolitic		1	5	9
Clay, blue, fine; hard at base	1	2	6	11
Sandstone, flinty, white; oolitic, interbedded with hard blue clay not oolitic		6	7	5
Flint		7	8	
Sand, oolitic, and blue clay; in four alternating beds		6	8	6
Limestone, white; some hard white to blue clay and flints		8	9	2
Chert layer, oolitic		4	9	6
Clay, oolitic, bluish to buff; lenticular, few inches				
Shakopee dolomite:				
Limestone; surface irregular; rock has weathered appearance				

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[4] Cady, G. H., Geology and mineral resources of the Hennepin and La Salle quadrangles: Illinois State Geol. Survey Bull. 37, p. 39, 1919.

THE LITHOLOGY OF THE UPPER PORTION OF ST. PETER AND ASSOCIATED BEDS

In most places the St. Peter is overlain by the Platteville limestone except in the Calhoun County area where the Joachim is present and in the region around Ottawa where a large part of the overlying Platteville and any other subsequent beds of pre-Pennsylvanian age have been eroded away and Pennsylvanian strata or recent unconsolidated sediments rest directly on the St. Peter. In general the section at the contact of the Pennsylvanian beds and the St. Peter in the Ottawa-Utica area consists of 1 to 8 feet of non-bedded clay resting immediately on the St. Peter, overlain by 1 to 2 feet of coal which in turn is overlain by gray shale. The clay is commonly known as fire clay and has been sold as such. It is a white, plastic clay containing numerous St. Peter sand grains. Its contact with the underlying sandstone is not sharp and is usually not delimitable within less than 6 inches. In the Oregon-Dixon region a green shale or green sandstone is present between the St. Peter and the Platteville. This formation has been correlated[5] with the Glenwood shale of eastern Iowa. The formation is described, in the Dixon quadrangle, as consisting of 2½ to 7 feet of green shale locally sandy, and in the Oregon quadrangle principally of green sand with minor amounts of shale.

During the present investigation the Glenwood beds were noted at a number of places in the Oregon-Dixon area. The green color of the strata is the most persistent characteristic; otherwise the lithologic details of the formation vary considerably. The following section gives a specific illustration of the character of the Glenwood in the Dixon quadrangle.

Section of Glenwood formation in the NE. ¼ sec. 23, T. 23 N., R. 9 E.

	Thickness	
	Ft.	*In.*
Platteville		
Limestone, buff, in 8-inch beds; lower 2 feet sandy	12+	......
Limestone and shale, limestone nodules averaging about 10 inches in length in a gray clay matrix	1	6
Glenwood		
Shale, chocolate brown, gritty, thin bedded	2	6
Shale, greenish gray, irregularly bedded	6	......
Sandstone, very argillaceous, buff, in irregular beds about an inch thick; basal beds greenish	1	......
St. Peter		
Sandstone	3+	......
Covered		

In the SW. ¼ NE. ¼ sec. 29, T. 23 N., R. 10 E., an exposure of 7 feet of Glenwood contains interbedded red and green shales.

In the Brookville-Harper area in Lee County the St. Peter is overlain locally by 5 or 6 feet of green shale. The following section was measured at the center of the west line sec. 12, T. 24 N., R. 7 E.

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[5] Bevan, Arthur, The Glenwood beds as a horizon marker at the base of the Platteville formation: Illinois State Geol. Survey Rept. of Investigations 9, 1926.

Section in sec. 12, T. 24 N., R. 7 E.

		Thickness Ft.	Thickness In.
7.	Glacial drift	1	—
6.	Shale, green	—	10
5.	Sandstone, loosely cemented, coarse grained, stained brown by iron	5	—
4.	Covered	3	—
3.	Shale, sandy, greenish-gray	5	—
2.	Sandstone, top irregular, much stained by iron, fine grained, grades into massive sandstone below	6+	
1.	Covered		

In this section beds 3 to 6 inclusive are probably Glenwood and bed 2 St. Peter.

Another outcrop of green Glenwood sand was noted in Winnebago County along Sugar River, in the NE. ¼ sec. 32, T. 29 N., R. 11 E., near Shirland, where the following section is exposed:

Section in sec. 32, T. 29 N., R. 11 E.

		Thickness Feet
9.	Sand, glacial	1+
8.	Limestone, dense, gray	10+
7.	Covered	8
6.	Sandstone, fine grained, firmly cemented, quartzitic in appearance, top and bottom irregular; grades into bed beneath it	1
5.	Sandstone, yellow, mottled with white	8
4.	Covered	10
3.	Sandstone, green, locally contains discoidal clay inclusions	8
2.	Sandstone, streaked, white, brown and red	5
1.	Covered	

In the above section bed 8 is Platteville limestone, beds 3 to 6 probably Glenwood and bed 2 St. Peter. An analysis of the green sand of bed 3 showed 0.51 per cent ferric oxide.

As stated by Bevan[6] the sandy Glenwood consists principally of large and small grains, with medium size grains only minor amounts. A sieve analysis of bed 6 of the above section is given in the table of fineness tests (Table 10, p. 148) as sample No. 63, and bears out this statement. It is of interest to note that 28.0 per cent of the sample was coarser than 65 mesh, and 64.6 per cent finer than 100 mesh. These two sizes might roughly be considered the coarse and fine grades. The medium sand constitutes then but 11.3 per cent of the sample. Comparison of these figures with other analyses of the St. Peter shows that the medium grade is below the average amount.

Throughout the State generally, the St. Peter is reported as being directly overlain by limestone. There are a number of exceptions, however, some of which are:

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[6] Bevan, Arthur, op. cit., p. 8.

County	Town	St. Peter overlain by
Whiteside	Sterling	35 feet shale and limestone
Carroll	Savanna	12 feet blue shale
Lee	Dixon	50 feet shale
DeKalb	Sycamore	30 feet shaly dolomite
	Genoa	42 feet sandy limestone
Kankakee	Kankakee	15 feet dolomitic limestone, locally sandy and containing beds of green shale
McHenry	Woodstock	41 feet sandy limestone

The log of a well at Malta, DeKalb County, gives the following sequence of beds:

		Thickness *Feet*
6.	Limestone (Platteville-Galena)	210
5.	Limestone, sandy	2
4.	Sandstone	18
3.	Shale, sandy	2
2.	Shale, gray	23
1.	St. Peter sandstone	

In some places there is a sharp line of separation between the St. Peter and Glenwood, suggestive of an unconformity. In others there is a transition zone. Transition zones are not, however, positive evidence that these formations are conformable inasmuch as the transition beds between them may have resulted from the commingling of sediments by the advancing Glenwood sea in much the same fashion as the sandy clay overlying the St. Peter in the Ottawa-Utica district was formed.

Thickness

The general thickness of the St. Peter is shown in Plate II by means of contours similar to those on topographic maps. In making this map, where a number of wells penetrate the sandstone in a limited area, a probable average local thickness has been computed and used, inasmuch as the map is not of such scale as to permit the delineation of minor local details. In areas where only a single record of the thickness of the sandstone is available it has not been possible to determine the local thickness or to evaluate the data so carefully.

An unusual instance of striking local variations in thickness is found at Joliet where wells record from 120 to 500 feet of St. Peter. A study of well logs throughout the State suggests, however, that 100 feet is the maximum common local variation in thickness.

Inasmuch as the upper surface of the St. Peter is subeven, it is apparent that the variations in thickness of the formation are accommodated for the most part in the beds underlying the sandstone, namely the Prairie du Chien series. The areas of thick sandstone shown in Plate II, therefore, indicate in a general way the depressions in the surface of the Prairie du Chien series.

STRATIGRAPHIC RELATIONS

The St. Peter sandstone is unconformable with the formations above and below it in outcrops throughout the State except in Calhoun County. The unconformity at the top of the St. Peter is in general undulating. The maximum local relief noted was about 50 feet. The unconformity at the base of the sandstone is much more pronounced; it has a local relief of about 350 feet in a limited area at Joliet. Elsewhere similarly abrupt relief of lesser magnitude is suggested by well records. This condition is thought, however, to be largely local, and the exception rather than the rule.

STRUCTURE

The map (Pl. III) showing the structure of the top of the St. Peter has been made from well records and outcrop data. The character of the data from which this map was drawn makes generalization a necessity, and a 200-foot contour has therefore been used. Inasmuch as the top of the St. Peter was a surface of erosion before its deformation, the map may not precisely indicate the actual rock structure. Some errors, introduced by pronounced local irregularities in the top of the sandstone, may be large, but in general the map is thought to delineate with reasonable accuracy the amount and character of the deformation suffered by the St. Peter.

The principal feature shown by the structure map is the La Salle anticline trending northwest-southeast through Ottawa and La Salle. The Savanna-Sabula anticline, really a cross fold on the La Salle anticline, is shown extending from Savanna in Carroll County to DeKalb in the county of the same name and causing an irregular, hour-glass shaped dome around Oregon in Ogle County where the two anticlines intersect. A slight arch trending northeast-southwest is also shown in the vicinity of Millington, Kendall County. This is partly responsible for the outcrops of the St. Peter sandstone at Millington and almost continuously along Fox River from its junction with the Illinois to Sheridan. There is also a suggestion of the Morris-Kankakee anticline extending southeast from Morris, Grundy County. In Calhoun and Jersey counties the effects of the Cap-au-Gres fault and the attendant folding are indicated. In the vicinity of Waterloo and Thebes the effects of the uplift of the Waterloo and Valmeyer anticlines at the former place and the Thebes anticline at the latter are shown by the comparatively shallow depth at which the St. Peter is encountered here as compared with the region adjoining.

The structure map (Pl. III) not only is of scientific interest but also is of value in the determination of the approximate depth to the sandstone at any given place. A knowledge of this depth is often desirable in searching for potable water supplies, inasmuch as the St. Peter is a very important source of water for domestic consumption. Two examples will serve to indicate how the map may be used for this purpose. (1) A given town has an elevation of 700 feet above sea level. On the structure map it is found to lie half way between the +200- and +400-foot contour lines. The approximate elevation of St. Peter sandstone beneath this town is therefore about 300 feet above sea level. The depth to the sandstone at the town is the difference between the elevations of the surface of the ground and of the top of the sandstone, or 400 feet. (2) A given town has an elevation of 650 feet above sea level and on the structure map lies one-fourth of the distance between the —400- and the —600-foot contour lines from the 400-foot contour. The elevation of the top of the St. Peter at this place is therefore 450 feet below sea level. Since the town is above sea level its elevation is added to 450 to give the depth of the sandstone or 1100 feet.

ORIGIN OF THE ST. PETER SANDSTONE

The origin of the St. Peter sandstone has long been a question of much interest to geologists. Two theories have been advanced, the first postulating the St. Peter as a great interior desert of drifting sand before burial and the second considering the sandstone as a sedimentary deposit essentially marine in origin. The most recent work on this subject is that of Dake[7] who from a comprehensive study of the St. Peter concludes that the sandstone is principally of marine origin except in some of the shore phases, that the source of the sand was the pre-Cambrian crystalline rocks and the Potsdam sandstone exposed in the Canadian shield north and northwest of the St. Peter basin, and that the sand was transported by streams from its source area to the epicontinental sea in which it was deposited and distributed principally by waves and currents. There may also have been minor distribution of beach sand by wind into dunes and related deposits which later were buried by the advancing sea. The evidence on which his conclusions are based and a statement of them in summary form are as follows:[8]

"1. The composition and texture of a sandstone may furnish criteria regarding its derivation and transportation, but not regarding its method of deposition.

2. The history of the sand grains of a sandstone is usually so complex, including transportation successively by winds, streams and waves, that textural criteria afford no proof whatever of the nature of transportation even to the *last deposit in which the sand is found.* The complexity of this history may be still further increased, if the sand passes through several cycles, from solid rock through sediment to solid rock again.

3. The structural and stratigraphic relationships in the field, including such features as the character of bedding, cross-bedding, unconformities, lateral gradation and similar associated phenomena, constitute the only valid criteria for determining the conditions under which a deposit was last laid down, and these may sometimes give a clue to the method of transportation *to that particular resting place.*

4. The purity of the St. Peter sandstone, while very remarkable, as compared with that of average sandstones, is, in respect to content of clay, iron, mica, heavy minerals, and carbonate, not sufficiently different from that of associated marine sandstones to demand any essentially different explanation of origin; the degree of difference actually

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[7] Dake, C. L., The problem of the St. Peter sandstone: Univ. of Missouri School of Mines and Metallurgy Bull., technical series, vol. 6, No. 1, p. 224, August, 1921.

[8] Dake, C. L., op. cit., pp. 221-224.

existing being satisfactorily accounted for by assuming its derivation from one of the older, already well-sorted sandstones, the Potsdam.

5. Size of grain, *in pure quartz sands,* in general, is limited by the size of quartz grains in average igneous rocks, and is not a satisfactory criterion of wind-blown sands.

6. The size and uniformity of grain in the St. Peter is so near that of the Roubidoux marine sand that no discrimination as to origin can be made on such a basis.

7. The degree of rounding and frosting of grains, which has been used as one of the chief arguments for eolian origin of the St. Peter, may often be masked by secondary quartz enlargement, but making due allowance for such modification, the St. Peter cannot be distinguished on this basis from the marine Roubidoux, or from older Cambrian sandstones, so that it is quite illogical to assume a different explanation for one than for the other.

8. The St. Peter shows bedding better developed than cross-bedding, and does not show typically developed dune-structure, even in the protected basal layers in the valleys of the old erosion surface.

9. There is no reason why, if the St. Peter is a dune deposit, an encroaching sea should be assumed to have completely worked out all such structure, and yet be assumed to have allowed it to be preserved, as reported in the Sylvania sandstone.

10. The St. Peter basal conglomerate of chert pebbles, widely developed on the pre-St. Peter erosion surface, shows no effect of wind-polishing or development of facetted pebbles characteristic of work done by drifting sand. Such wind modification would surely be observable if the St. Peter sand was drifted extensively across the area.

11. Limestone layers occur at many horizons, particularly at the south, but are known as far north as north central Iowa and northern Illinois, and indicate marine deposition.

12. Oscillation ripple-marks in sand layers, marine fossils in limestone beds, and extensive limestone deposits in general, occur in Arkansas and Missouri, next above the unconformity, showing submergence before the advance of the sand into the region.

13. Marine fossils are found in the St. Peter as far north as Minneapolis, not only in the uppermost transition layers, but also at three horizons, more than 60 feet below the top. These would not appear to have resulted from working over of dune deposits.

14. The St. Peter and Roubidoux appear to have been derived from a common land mass, which was almost certainly located to the northward, on the present site of the pre-Cambrian shield.

15. This land mass was not very high, sloped toward the sea at the south in which direction its rivers flowed, was probably moderately humid, but without vegetation because land plants had not yet developed, and lay in the belt of prevailing westerly winds.

16. Throughout early Paleozoic times, these conditions were particularly favorable for wind action, the westerly winds tending to float the finer dust and clay eastward across a continuous land mass until it was lost in the Atlantic, whereas the sand was drifted into the rivers and carried south to the sea, thus accounting for the lack of the theoretically proportionate amount of clay in the early Paleozoic sandstones.

17. The wind drifting undoubtedly was also an important factor in the rounding and frosting of sand grains in all the early Paleozoic sandstones from Potsdam to St. Peter.

18. Since these winds were presumably from west to east then as now, being controlled by the rotation of the earth, they would not seem competent to drift the St. Peter sand southward from its place of origin to its present distribution.

19. The land mass included not only the pre-Cambrian mixed crystallines, but also a broad fringe of Potsdam sandstone, which was exposed, possibly about the close of Everton time, by the erosion of the overlying Beekmantown limestones.

20. The derivation of the St. Peter largely from this Potsdam belt, in which the sands were already well assorted and rounded, together with the added sorting and rounding by wind work in the supply area, and by waves in the sea, explains in a wholly satisfactory manner the high degree of purity and rounding of its grains.

21. These sands were delivered to the sea both by rivers and to a minor degree directly by winds, and were distributed chiefly by waves and currents.

22. The shores of this sea were fluctuating, but during middle and late St. Peter time, were for the most part north of the Iowa-Minnesota line.

23. North of that line there is quite probably a small amount of St. Peter that is truly unmodified terrestrial deposit, for occasional slight local emergences not improbably allowed of wind-drifting and rounding, accounting for local areas of exceptionally rounded grains; but even here marine agencies were probably dominant in deposition.

24. South of the Iowa-Minnesota line, conditions of both transportation and deposition were almost wholly marine, and in this area there did not exist during any part of St. Peter time, a great interior desert of drifting sand."

The data secured during the present investigation tend to corroborate Dake's conclusions. Additional corroborative evidence of marine origin is presented along five different lines.

(1) *Worm borings.* In Chapter III worm borings are described from the middle St. Peter of the Ottawa district. Similar borings were also reported by Freeman.[9] The borings are preserved in sandstone doubtless deposited by water and are probably the borings of marine worms, suggesting marine conditions during at least part of middle St. Peter time.

(2) *Ripple marks.* The upper and lower St. Peter in northern Illinois and the middle of the formation in Calhoun County contain ripple marks which are described in Chapter III. These are of the oscillation type commonly developed in shallow water.

(3) *Dessication or sun cracks.* In Chapter III dessication cracks are described from the middle St. Peter in sandstone with a high clay and probably a high colloidal silica content. The presence of these cracks in well-stratified sandstone in horizontal and parallel beds suggests temporary emergence and subsequent submergence of water-laid sediments.

(4) *Uniform character of clay.* As suggested in Chapter III the uniform character of the clay of the St. Peter is best explained by postulating a principally marine origin for this material.

(5) *Relation of bedding and cross-bedding.* Dake's contention that bedding in the St. Peter is far more important than cross-bedding is thoroughly confirmed from the detailed study of the St. Peter of Illinois. This is thought to favor marine origin for the bedded sandstone. Furthermore, such cross-bedding as is present in the Illinois St. Peter is generally of the aqueous rather than the eolian type.

(6) *Similarity between the St. Peter sand and the New Richmond sand.* A comparison of the shape, size, degree of rounding, frosting, and texture of samples of St. Peter sand and the New Richmond sand from outcrops in Illinois fails to reveal any significant difference between the two. Two unlabeled samples of these sands would be indistinguishable. The sieve anaylsis of a sample of New Richmond is given in the table of fineness tests (Table 10, No. 59). The presence of the New Richmond formation of interbedded limestone of marine origin suggests that the sandstone may also be marine,

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[9] Freeman, S. H., Geology of Illinois, La Salle County, vol. 3, p. 280, 1882.

and that sand of the physical character of the St. Peter may accumulate as a marine deposit.

(7) *Limestone and dolomite.* The presence of limestone or dolomite beds in the St. Peter of Lake, Cook and Adams counties (see p. 50) indicates that in parts of Illinois at least some of the formation is marine in origin and suggests that parts of the sandstone elsewhere in the State may have had a similar origin.

Geologic History

After the deposition of the Shakopee formation in Illinois, a period of uplift, accompanied by slight deformation, occurred and a long period of erosion ensued. It is doubtful if erosion was very rapid despite the fact that streams cut deep valleys in the Shakopee, for in places there accumulated on comparatively narrow divides considerable thicknesses of residual clay. It seems likely therefore that solution played a very important part in shaping the pre-St. Peter land mass. In many places the residuum from the limestone seems to have been cleaned largely of clay and to have consisted principally of residual chert fragments.

The St. Peter sea advanced on a land mass of considerable dissection. The result was many drowned valleys and irregular submerged areas. Some of these areas were out of direct communication with the streams bringing the sand into the sea and in them the sediments of early St. Peter time were largely residual material from the Shakopee carried down by the surface runoff, and a little sand. The sandy shales in the base of the St. Peter are doubtless of this origin. In places the waves and currents working on the Shakopee land mass cleaned away the clay and carried it to deeper and quieter water where it was deposited interstratified with sand. During the transgression of the land by the sea, residual cherts from the limestone became available to the waves and currents and were mixed with the sand thus yielding the sandstone and chert so commonly reported in the lower St. Peter. In other places it appears that the waves and currents were principally depositing their loads and that temporary beaches, bars and sandy flats were formed. The sand, in such places where the winds carried it landward, buried the deposits on the old Shakopee land mass and, as submergence ensued, the waves and currents reworked, at least partially, the wind-blown sand but apparently did not work deeply enough to disturb the underlying materials to any great extent, probably because the St. Peter sea was essentially a depositing rather than an eroding sea. Thus it seems that some of the red clay found on what appear to be Shakopee divides, may have been preserved through the transgressional period of the early St. Peter sea. In local, quiet areas intimately mixed sand and clay were deposited, together with some calcareous material. The clay and calcareous material served to bond the sand and to preserve the ripple marks of that early sea.

The source of the St. Peter sand was probably the pre-Cambrian crystallines of the Canadian shield and the Cambrian and early Ordovician sandstones lying north of the area of St. Peter deposition.[10] The fact that the crystallines were probably well weathered and the Cambrian sandstones not very firmly cemented doubtless resulted in an abundant and readily available supply of sand to the agencies transporting it to the area of St. Peter deposition. Gradual and continued depression of the St. Peter basin resulted in practically continuous deposition of sand in Illinois during the greater part of middle and late St. Peter time though in places, especially during late St. Peter time, areas existed where conditions were favorable for the accumulation of calcarerous and dolomitic muds, as evinced by the presence of limestone and dolomite in the middle St. Peter.

In the Calhoun County area deposition was apparently continuous from St. Peter to Joachim time, with a gradual change in the character of the sea from one depositing sand to one depositing calcarerous material. In northern Illinois, however, the upper St. Peter sediments have been removed by erosion, and consequently the events of late St. Peter time are not decipherable. It cannot be definitely stated whether or not the Joachim dolomite existed in northern Illinois, but if it did exist it was eroded before the deposition of the Platteville sediments.

The erosion occurring in northern Illinois after the close of St. Peter deposition and before the deposition of the next overlying formation was apparently not severe. Probably the land was not high above the sea. The result was the development of a subeven surface which is now the contact between the St. Peter and the overlying beds.

Following this period of erosion the land was again submerged and in a part of northern Illinois clay mixed with St. Peter sand was deposited making the Glenwood formation. Elsewhere in Illinois, the sea seems to have been free from muds and the sand of the St. Peter was overlaid by deposits of lime muds and fossil debris which later became the Platteville-Galena limestone and dolomite.

Folding of the La Salle anticline took place principally some time after Galena time and before Pennsylvanian times[11] and subsequent to this folding erosion removed the beds overlying the St. Peter in the La Salle area. With the submergence during the Pennsylvanian period a clay mixed with sand derived from the St. Peter was deposited by the Pennsylvanian sea.

With the close of Pennsylvanian time the land again appears to have been uplifted and the erosion which is partly responsible for the present configuration of the bed rocks of the State began. Later, during the Pleistocene or glacial period, at least two continental ice-sheets overspread the

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[10] Dake, C. L., op. cit., p. 207.

[11] Cady, G. H., The structure of the La Salle anticline: Illinois State Geol. Survey Bull. 36, p. 174, 1920.

then existing outcrops of St. Peter and in places buried them with a deposit of glacial clay and gravel. The swollen streams associated with the melting of these glaciers were further effective in eroding the St. Peter in northern Illinois and it is probable that these glacial waters of Illinois and Fox rivers were in a large measure responsible for the development of the rock terraces in the valleys of these streams. Subsequent and recent erosion has removed some of the glacial drift from the outcrops of St. Peter and is to a large extent responsible for the present minor details of topography.

CHAPTER III—SPECIAL LITHOLOGIC, STRUCTURAL, AND COMPOSITIONAL FEATURES OF THE ST. PETER SANDSTONE

INTRODUCTION

In Chapter II the general areal geology and lithologic character of the St. Peter sandstone are described and some of the special features of a lithologic, structural, and compositional nature are alluded to. In this chapter these special features are discussed in detail.

STRUCTURAL FEATURES

BEDDING

In general the St. Peter may be said to be a bedded sandstone, though the bedding is thicker and less apparent than that common to sandstones. The thickness of the St. Peter beds varies from 3 to 10 or 12 feet, though locally much thinner beds are present. In the molding sand quarries in the Illinois River bluff west of the center of sec. 13, T. 33 N., R. 2 E., the upper beds exposed are thin, varying from 1 to 5 inches in thickness and averaging about 3 inches. In the glass sand quarries occur locally layers of thin-bedded sandstone with a highly siliceous cement. In some places the bedding planes are clearly brought out by a deposit of iron hydroxide along them, but commonly the general absence of considerable amounts of clay or other impurities causes the sandstone to appear non-bedded on casual examination. Bedding planes are in general not marked and the most reliable method of determining bedding is observation of the sandstone from a distance or close examination of the variations in the size of the dominant grain of a vertical section.

CROSS-BEDDING

Cross-bedding is not common in the St. Peter but is well developed in some places, particularly in the quarries of the Wedron and United States Silica Companies (figs. 5 and 9). In general the cross-bedded zones are not more than 3 feet thick. In the quarry of the United States Silica Company (fig. 9), the exposure consists of a single cross-bedded stratum about 3 feet thick and also of cross-bedded strata inclined in a number of directions with the different sets of beds truncating or truncated by others. Most of the cross-bedding noted in the St. Peter generally was in the middle portion of the formation though it also occurs elsewhere in the formation. Both fluvial and probably eolian cross-bedding is present in the St. Peter though the former is far more common.

Another feature of the St. Peter is the "sheety" structure which is commonly developed in weathered and some fresh exposures (figs. 6 and 21). Almost all of the sheety planes are inclined at a steep angle to the face of the exposure and their strike is generally roughly parallel to it. The origin of the structure is not known, but it is thought that it may be a phenomenon of bedding, or of the weathering of a rather homogeneous sand, or of fracturing.

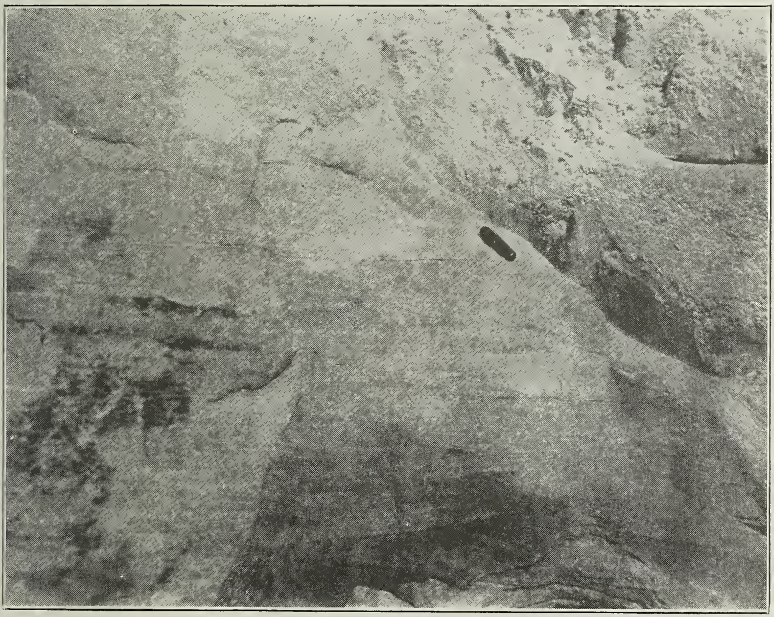

Fig. 5. Cross-bedding in the St. Peter sandstone in the quarry of the Wedron Silica Company. The knife indicates the comparative size of the cross-bedded layers. The black specks along some of the bedding planes at the right of the picture are small masses of interstitial marcasite.

RIPPLE MARKS

In general ripple marks are rare in the St. Peter sandstone. Their absence is not thought to indicate that they did not exist in the St. Peter sea, but rather that conditions were not favorable for their preservation. The most extensively ripple-marked sandstone noted was that exposed in Calhoun County between Dogtown Landing in the SW. corner sec. 29, T. 12 S., R. 2 W., and West Point Landing about a mile north. The ripple marks are of the oscillation type, and vary from 1 to 1½ inches from crest to crest and average about ¼ inch in depth. They commonly anastomose.

In northern Illinois ripple marks were observed principally in the lower part of the St. Peter. The ripple-marked slab shown in figure 7 was found in an outcrop of lower St. Peter in the north bank of Franklin Creek in the NW. ¼ NE. ¼ sec. 33, T. 22 N., R. 10 E. The ripple marks in this exposure as a whole are of two kinds: those which are straight and roughly parallel, measuring about one inch from crest to crest, and those which anastomose, averaging about 3½ inches from crest to crest and about ½ inch in depth. Both are of the oscillation type.

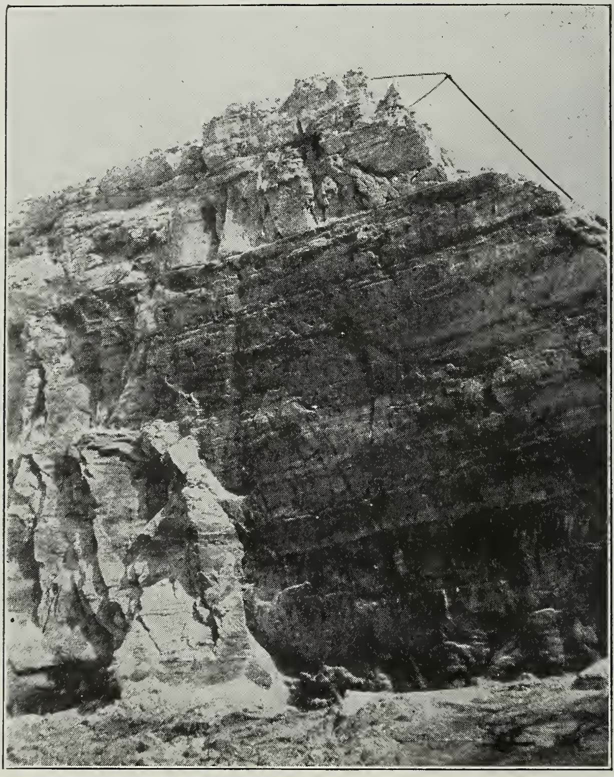

Fig. 6. Exposure of St. Peter sandstone in the quarry of the Wedron Silica Company showing in the left hand portion the "sheety" structure of the sandstone and on the right the face of one side of a joint. The black streakings on this face are thin sheets of marcasite.

Other exposures of ripple-marked sandstone were found in the small gullies in the northeast bank of Franklin Creek in the NE. corner sec. 3, T. 21 N., R. 10 E., and vicinity. The ripple marks are of the oscillation type and vary from 1½ to 3 inches from crest to crest and average ½ inch in depth. The trend of the troughs of these ripple marks is roughly N. 30° W.

The only ripple marks noted in the upper St. Peter were found northwest of Shirland in Winnebago County near the center of sec. 32, T. 29 N., R. 11 E., in the south bank of Sugar River. They are of the oscillation type.

An attempt was made to locate the eolian ripple marks in Ogle County mentioned by Worthen.[1] However, it was impossible to find the locality from the data given.

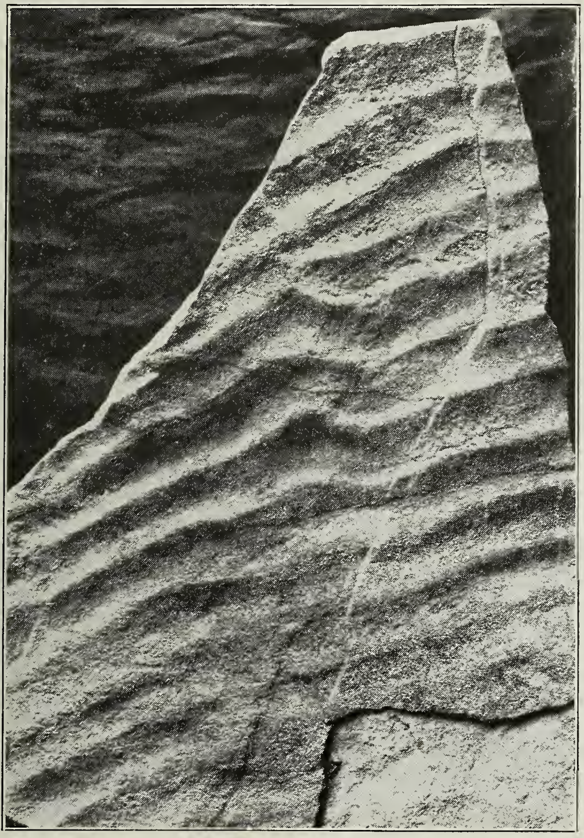

Fig. 7. Slab of ripple-marked St. Peter sandstone from outcrop in NW. ¼ NE. ¼ sec. 33, T. 22 N., R. 10 E. (One-sixth natural size.)

HONEYCOMB WEATHERING

In places weathered faces of St. Peter are covered with a large number of pits so arranged that they give the appearance of a honeycomb to the surface of the rock. This phenomenon is known as honeycomb weathering and is commonly ascribed to the process of differential weathering of sandstone with an unequally distributed cement. It is very well shown in Council Cave in the NW. ¼ sec. 25, T. 33 N., F. 2 E.

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[1] Worthen, A. H., Geology of Illinois. Ogle County, vol. 3, p. 18, 1882.

WORM BORINGS

In some of the quarries in the St. Peter sandstone, especially those of the United States and Commonwealth Silica Companies, there are beds of sandstone of finer grain and more firmly cemented than the rest of the deposit which contain roughly vertical tubes from ⅛ to ¼ inch in diameter filled with sand which is coarser than the matrix. The original tubular openings are thought to have been made by worms and subsequently filled by coarser sand washed into the borings (fig. 8). These borings are probably similar to those noted in the St. Peter of the same region by Freeman.[2]

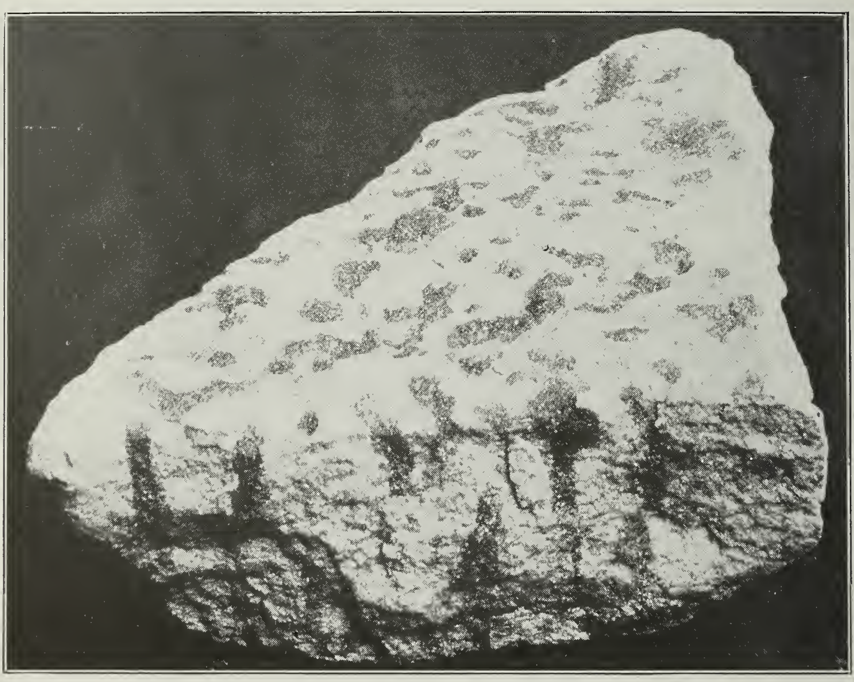

Fig. 8. Worm borings in the St. Peter sandstone.

Worm borings have also been described[3] from the exposures at the south end of the Rock River bridge at Grand Detour 65 feet below the top of the formation, and in the NE. ¼ sec. 23 N., R. 10 E., 10 feet from the top of the sandstone. The borings were identified as *Scolithus minnesotensis* Hall.

DESSICATION OR SUN CRACKS

In the glass-sand quarry of the Higby-Reynolds Silica Company (Reynolds east quarry) some of the thinner and more firmly cemented upper

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[2] Freeman. S. H., Geology of Illinois, vol. 3, p. 280, 1882.

[3] Knappen, R. S., The geology and mineral resources of the Dixon quadrangle: Illinois State Geol. Survey Bull. 49, p. 51, 1926.

beds containing a high content of fine silica, possibly of colloidal origin, show dessication cracks filled with sand. This phenomenon was also noted locally in thin-bedded strata in other quarries but was best and most commonly exposed in the Reynolds quarry.

Compositional Features

CARBONACEOUS BANDS

Locally thin horizontal or approximately vertical bands of carbonaceous or fibrous organic materials, rarely over ½ inch thick, were noted in the upper few feet of the St. Peter. The best exposures were seen in the west face of the quarry of the National Silica Company at Oregon. They have been formed from rootlets which penetrated into the sandstone through cracks and spread out laterally in porous or soft portions of the sandstone.

CLAY POCKETS

In the molding sand quarries in the Illinois River bluff between Ottawa and Utica deposits of clay are found locally in depressions in the surface of the St. Peter sandstone. The depressions are commonly roughly conical and approximately round. The largest of the clay pockets observed was about 12 feet in diameter and had been excavated to a depth of about 8 feet without reaching bottom and probably extended at least 8 feet deeper. At the quarry of the Illinois Valley Silica Company it is reported that three clay pockets were encountered, a large central pit with a smaller pit on either side of it. The small pits were connected with the large pit. The small pits were about 10 feet deep; the large one was 65 feet deep, 15 feet in diameter at the top and 8 feet at the bottom. The clay filling these depressions is similar to that which overlies the sandstone in the region where the depression occurs. So far as could be ascertained these pockets are entirely filled with clay and contain no boulders or extraneous material in their lower portions. Their origin is not known, but it may be suggested that they are the result of differential erosion by water or wind of a portion of the sandstone less firmly cemented than the rest, and that this erosion, if by wind, took place immediately before the submergence which permitted the deposition of the overlying clay; otherwise the depressions would probably have been obliterated.

INTERSTITIAL ORGANIC MATERIAL

In the quarries of the Standard Silica Company (Plant No. 1) and of the National Plate Glass Company there are present locally, in the upper portions of the exposures, bands of sand of a much darker color than that due to the presence of iron. At the Standard quarry the exposure of these brown bands was as follows:

		Feet
6.	Soil, black	
5.	Sandstone, brown	1
4.	Sandstone, gray white	3
3.	Sandstone, brown	3
2.	Sandstone, gray white	4
1.	Sandstone, brown	1

A test made on a sample of sand from bed No. 3 showed that the color was not due to iron but to the presence of between 0.1 and 0.2 per cent of organic material which occurs as a coating on the sand grains and mixed with the interstitial clay. It is probable that descending water carried this organic material down into the sandstone and that different positions of the ground-water table governed its deposition.

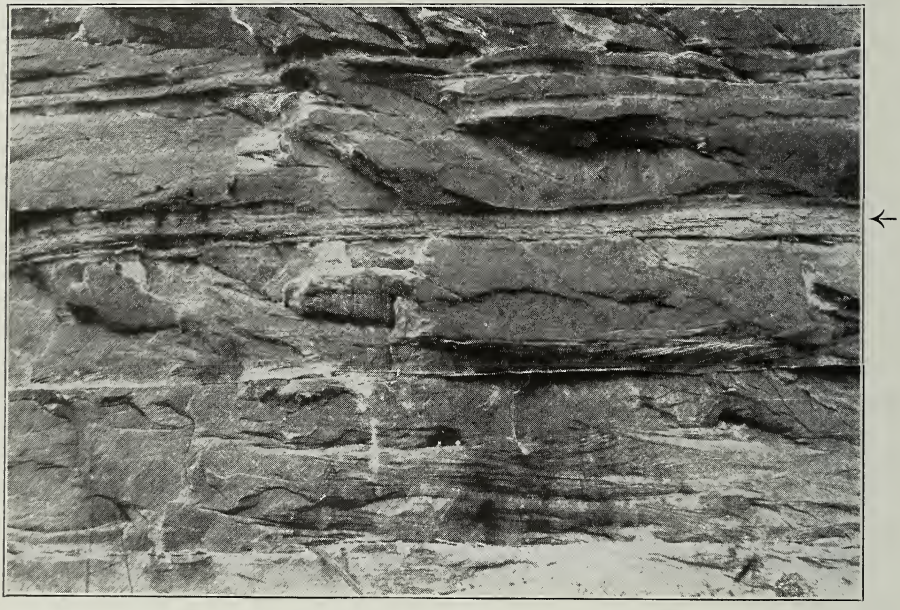

Fig. 9. "Magnesia" bed (indicated by arrow) and cross-bedded sandstone in the quarry of the United States Silica Company.

"MAGNESIA" BEDS

In certain of the St. Peter quarries there are present, usually in the middle portion of the formation, beds of thin-bedded, fine-grained sandstone relatively high in clay and relatively firmly cemented, known as "magnesia" beds in the parlance of the quarrymen (fig. 9). They are the most persistent stratigraphic and lithologic unit found in the St. Peter of Illinois. They vary from a few inches to 3 or 4 feet in thickness and contain most of the recognizable worm borings and sun cracks found in the exposures of the St. Peter in Illinois. They are equally stained or mottled pink or yellow by iron oxides.

The analysis of sample 13a taken from the bed shown in figure 9 is represented graphically in figure 10. It bears out the statement regarding the fineness and clay content of this type of material and shows that 48 per cent of the sample is finer than 65 mesh, 12.3 per cent finer than 200 mesh, and 5.8 per cent clay. Another sample, No. 31, from a somewhat thicker bed of the same sort, contained 22.5 per cent finer than 65 mesh, but only 2.2 per cent finer than 200 mesh.

It is doubtless these beds to which Littlefield refers[4] when he speaks of the presence of magnesium in the middle portion of the St. Peter. None of the samples tested during the present investigation contained an appreciable amount of magnesium, and the term "magnesia" for these beds seems therefore somewhat of a misnomer. It may be, however, that they represent a leached phase of the sandy limestones or dolomites reported elsewhere in the State, and so may in places contain small amounts of magnesium carbonate or oxide.

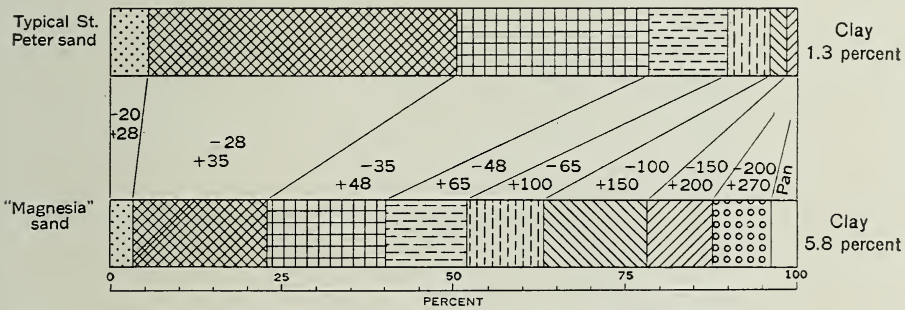

Fig. 10. Graphs showing texture of typical St. Peter sand and of "magnesia" sand (sample 13a).

SILICEOUS JOINT FILLINGS

In many places joints in the St. Peter sandstone have been partly or wholly filled by secondary deposits of silica in which are usually included a number of medium or coarse, rounded sand grains. The secondary silica is commonly opaque and white and has a dull luster. It is thought that these joint fillings have been formed by precipitation of silica from ground water and that the sand grains were mechanically enmeshed in the deposit.

The siliceous deposit commonly scales off parallel to the faces of the joint which it fills. In some places where most of the deposit has scaled off the partly impregnated joint face which has been left bare appears to have a poorly slickensided surface (fig. 11). When outcrops containing these siliceous veins weather, the friable sandstone adjoining the vein is removed and the veins are left as dike-like ridges.

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[4] Littlefield, M. S., Natural-bonded molding sand resources of Illinois: Illinois State Geol. Survey Bull. 50, p. 124, 1925.

FEATURES OF THE SAND GRAINS

SIZE

As shown by the table of sieve analyses (p. 148) the maximum quantity of sand retained on the 20-mesh sieve was 0.7 per cent, and in general almost all of the sand retained on this sieve will pass 16 mesh. It may be safely said, therefore, that for all practical purposes the maximum size of the

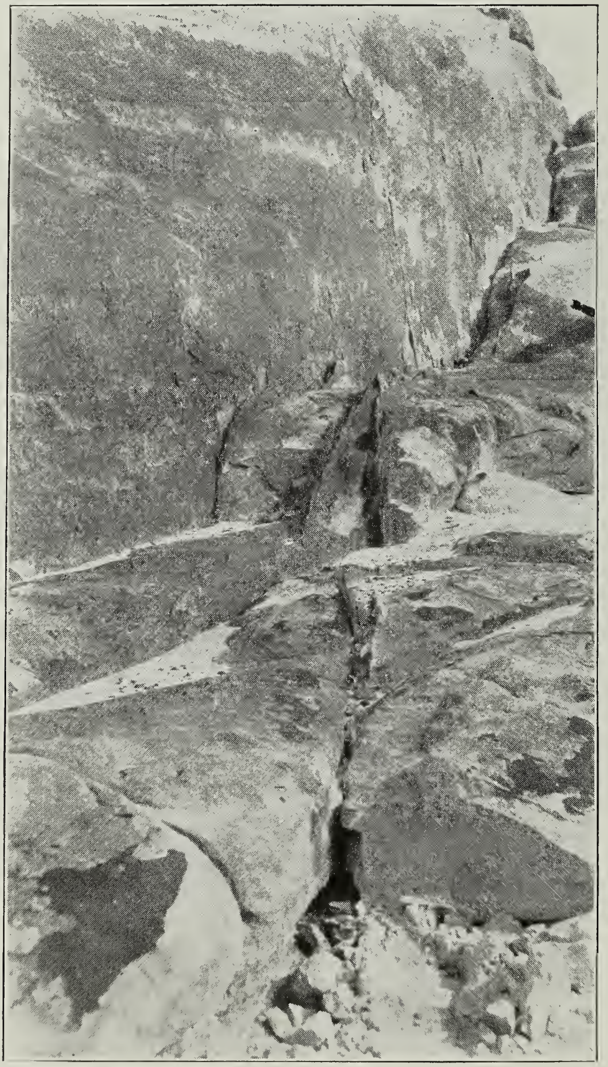

Fig. 11. Eroded siliceous veins in the unworked portion of the quarry of the Ottawa Silica Company. Note the pseudo-slickensided surface of the rock in the upper left hand portion of the picture.

grains of the St. Peter sand is through a 16 mesh and on a 20 mesh (0.711 to 1.000 mm.). The smallest sieve size determined was through 270 mesh (about 0.056 mm.). A maximum of 4.0 per cent of material of this size is

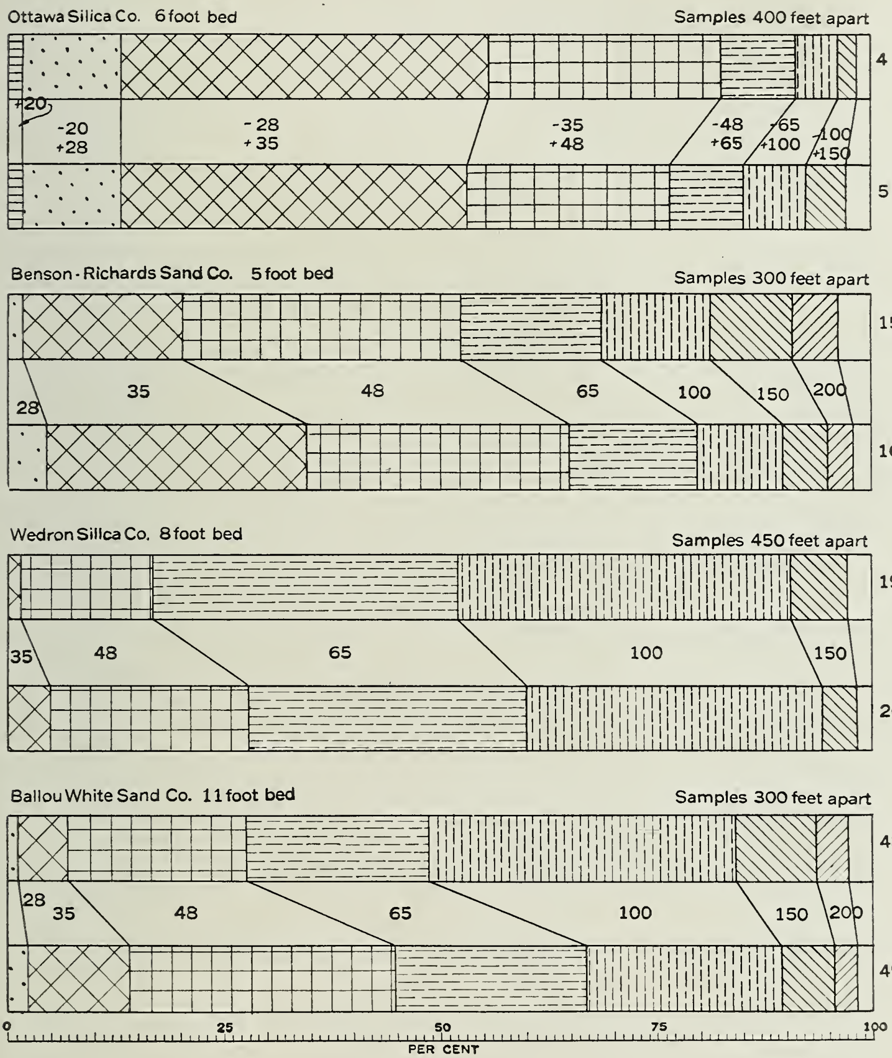

Fig. 12. Sieve analyses of sand from given beds in four different quarries. Sample numbers are indicated at right of diagram.

shown by the analyses. The sample containing this maximum amount was taken from a weathered outcrop and may possibly have been somewhat influenced by mechanical weathering. The maximum quantity of material from an unweathered sandstone passing the 270-mesh sieve was 1.5 per cent. The analyses show that in general the bulk of the sand grains will pass a 28-mesh sieve and be retained on 100 mesh.

In order to determine the persistence of the physical composition of given beds of the St. Peter, eight samples, two from each of four different exposures, were taken which were designated "bed" samples. They were not taken from the same bed in the four outcrops, but both samples from a given quarry came from one bed. The sieve analyses of these bed samples are given in the table of fineness tests (Table 10, p. 148) and are also indicated graphically in figure 12. The outstanding features shown are as follows: Samples 4 and 5 show rather striking similarity indicating a bed of uniform texture and relative coarseness. Samples 15 and 16 show a marked variation in the amount of 35-mesh sand present and minor variations in the rest of the sizes. The sand is in general of a medium size. Samples 19 and 20 are both fine; the bulk of the sand passes the 35-mesh sieve. The principal variations in the graphs of these two sands occur in the amounts of sand retained on the 48-mesh sieve and on the 100-mesh sieve. The sand of samples 48 and 49 is also fine. The chief variations in these samples are also in the amounts of sand retained on the 48- and 100-mesh sieve. From these graphs it would seem that in general there is considerable variation in the texture of the sand in the beds of the St. Peter.

In order to determine the variation in the texture of the sandstone in larger units, a series of sieve analyses were conducted in the field on samples taken from three different faces of the quarry of the Ottawa Silica Company essentially comprised of the same beds, and the results are shown graphically in figure 13. Of note in these graphs is the variation in size of the sands of the different beds sampled. There are a few coincidences in the analyses of the sands in beds in the different faces. In the west face the sand from 8 to 11 feet above the floor of the quarry shows a close similarity to the sand from 7½ to 12½ feet in the south face; the sands from 15½ to 18½ feet in the west face and from 21½ to 25½ in the south face show equal amounts of 30 and 40 mesh. There are no similarities between the graphs from the south and east faces. The east and west faces, however, show a similar texture in the beds from 13 to 17 and 11 to 13 feet respectively. The average analyses indicate the average for the entire face.[5] The results of similar analyses made in the laboratory on samples taken in the same quarry at about the same places are shown in figure 14. Because field analyses were determined by volume, and laboratory analyses by weight, they are not directly comparable.

Figure 15 shows graphically sieve analyses of the samples from a number of quarries selected so as to represent the St. Peter geographically. The

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[5] This average is weighted so that it takes into consideration the thickness of the beds used in making the calculation.

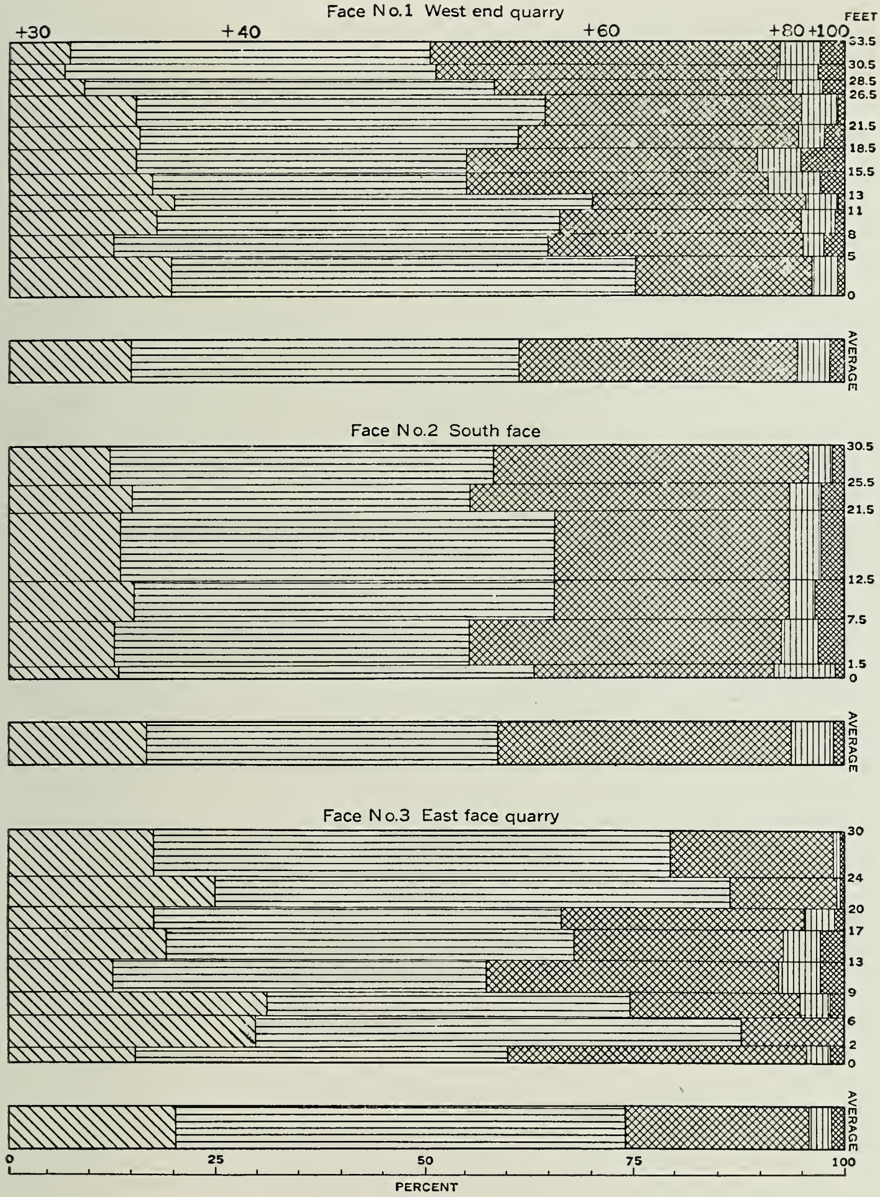
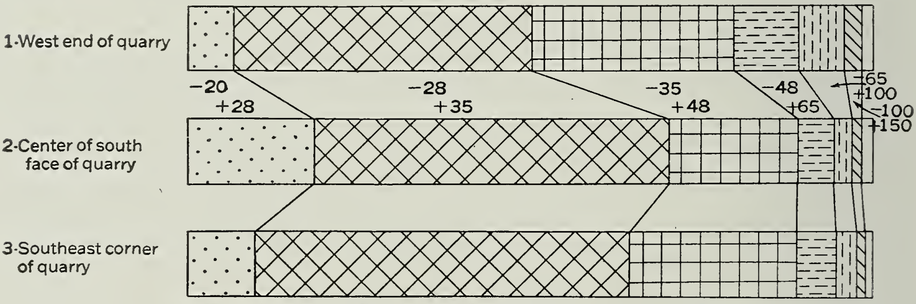


Fig. 13. Sieve analyses made in the field of samples taken bed by bed from the east, west, and south faces of the quarry, plant A, Ottawa Silica Company. The figures at the right indicate the height of the tops of the beds above the quarry floor. The percentages are by volume.

first three samples, Nos. 45, 43 and 7, are coarse sands as shown by the graphs and by the table of fineness tests (Table 10). They come from quarries near the eastern edge of the St. Peter sandstone outcrop, and are from the top of the formation as it is found now. The samples in order from left to right are taken farther and farther west in the outcrop in Illinois Valley, and include progressively lower strata of the St. Peter. Sample 36 is the lowest one available in the Ottawa-Utica district and probably comes from the middle portion of the St. Peter. From the graphs it appears that the upper part of the St. Peter in the Ottawa-Utica district is in general the coarsest part, with a gradual and not altogether constant decrease in the degree of coarseness toward the middle portion of the formation.

Samples 18, 47, 52 and 60/61 come from outlying outcrops of the St. Peter and are included to show the comparative size of the sand found away from the Ottawa-Utica district It will be noted that these four samples are fine sands. With the exception of 60/61 the samples have been taken from the upper and upper middle parts of the St. Peter. The Calhoun County samples come principally from the middle portion of the formation.

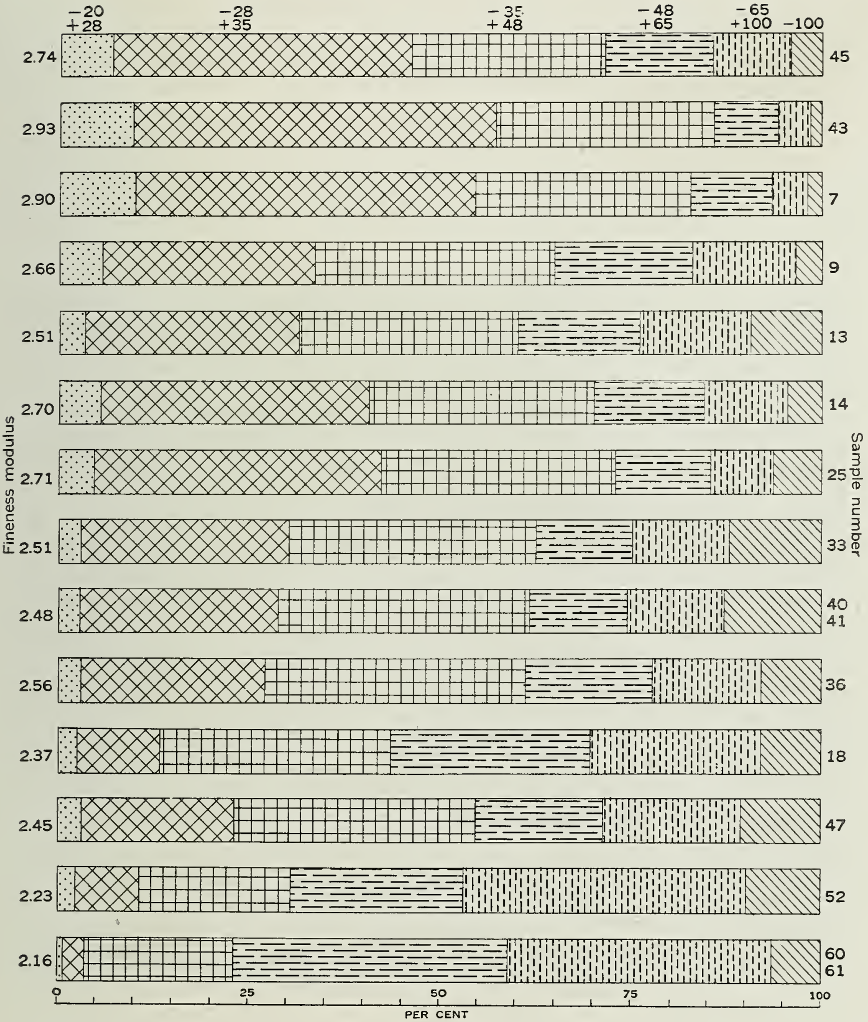


Distance from 1 to 2— 500 feet
Distance from 1 to 3—1600 feet
Distance from 2 to 3—1200 feet

Fig. 14. Sieve analyses in per cent by weight of face samples from the quarry of plant A, Ottawa Silica Company.

SHAPE

The sand of the St. Peter formation is widely and justly known as a "rounded" sand but the use of the adjective has often inferred that the grains of sand are round, or almost spherical. This is true only in a limited sense. There are some round, almost spherical grains and in general all of these will be retained on a 48-mesh and most of them on a 35-mesh sieve. Figure 16 shows a number of these large, round grains. Aside from these, however, most of the grains (figs. 16 and 17) are far from round and possess angular



Sample No.
7—Ottawa Silica Co.
9—Standard Silica Co.
13—U. S. Silica Co.
14—Benson-Richards Sand Co.
18—Wedron Silica Co.
25—Bellrose Sand Co.
33—Utica Fire Sand Co.

Sample No.
36—Higby-Reynolds Silica Co.
40/41—Amer. Silica Sand Co.
43—Standard Silica Co.
45—South Ottawa Silica Sand Co.
47—Ballou White Sand Co.
52—National Silica Co.
60/61—Calhoun County.

Fig. 15. Sieve analyses in per cent by weight of sand from exposures of St. Peter sandstone selected to show the variations in the texture of the sandstone in different localities.

corners or surfaces with reentrant faces. From an examination of figures 16 and 17 it is apparent that the finer grains are in general the more angular. Experiments described on pages 148-151 demonstrate the fact that in general the finer the St. Peter sand, the more angular it is.

FROSTING

The St. Peter sand has commonly been described as consisting of frosted grains. The coarse sand is frosted, and inasmuch as the large grains are the ones commonly observed megascopically or with a hand lens the statement is correct only in so far as it applies to them. Figure 16 shows some coarse grains which have frosted surfaces. Figure 17 shows somewhat more clearly the character of the surface of the medium-sized grains. It is apparent from this illustration that the frosted surface of the medium-sized sand is really formed by partial frosting with much chipping. The amount of frosting in general decreases with the size of the sand grains. The frosted surfaces of the coarser grains are very fine grained.

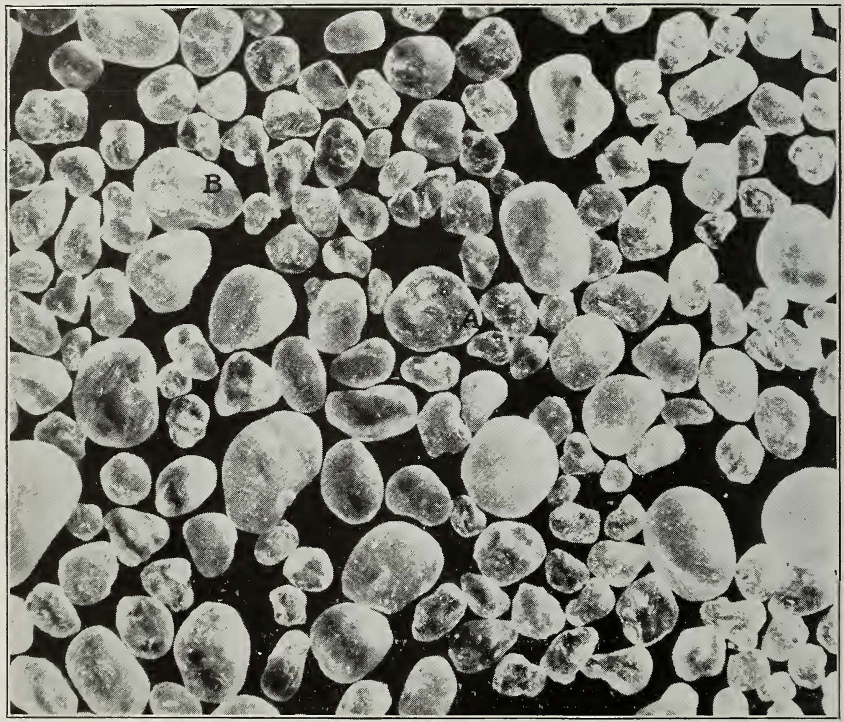


Fig. 16. St. Peter sand showing the character of the surface and shape of the grains. The grains marked A and B show respectively a pitted grain and the surface of a grain which has fitted into a pit. Magnified about 20 times. (Photograph by courtesy of U. S. Silica Company.)

PITTING

Many of the St. Peter grains particularly those larger than 65 mesh, are conspicuously pitted. The pits are of two types: (1) those in frosted grains and (2) those in grains to which secondary silica has been added.

PITS IN FROSTED GRAINS

These pits in general greatly resemble the photographs commonly shown of lunar craters, that is they are shallow and broad. The maximum depth noted was about 0.1 millimeter. The width varies a great deal according to the size of the sand grain. The maximum noted was about 0.75 millimeter. The floors of these pits have slight irregularities, but are nearly flat in general, and some have frosted surfaces very similar to the frosted surfaces of the sand grains themselves. The pits have probably formed at the contact of two sand grains, for if the aggregates of two or more grains are selected from sand and washed to remove the clay, it will be found in a large per-

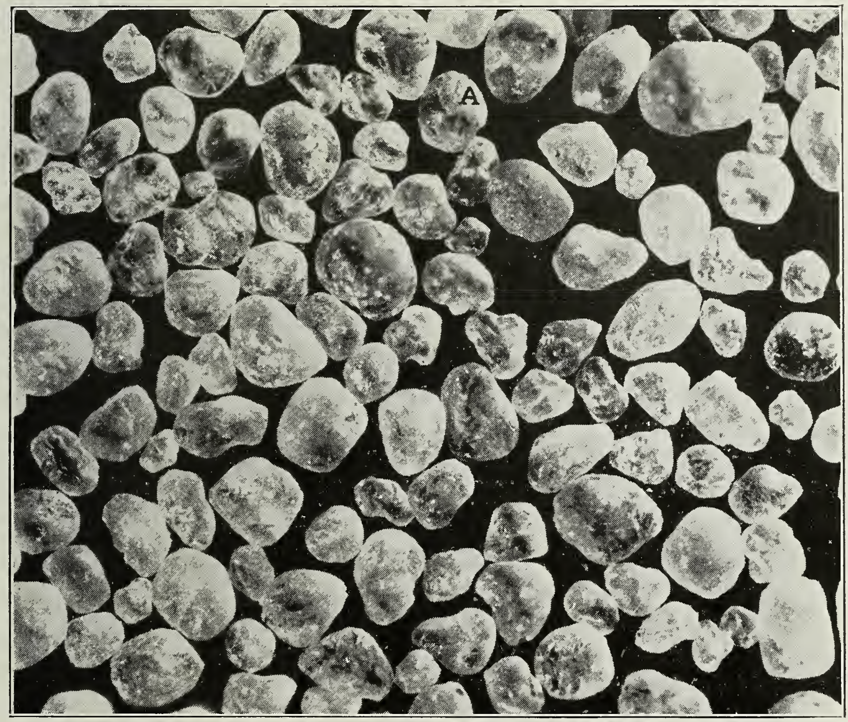


Fig. 17. Medium-sized St. Peter sand. These grains show the typical shape and surface of grains of this size. The grain marked A has two pits. A number of other grains also exhibit depressions. Magnified about 35 times. (Photograph by courtesy of U. S. Silica Company.)

centage of them that at the contact of any two grains either one grain is pitted and the other grain fits into the pit, or each grain shows a scar which is flat and the two scars are mutual counterparts. These two phenomena are illustrated in figure 16, by grains A and B respectively, and by some of the grains in figure 17.

The method of formation of these pits is not clear, but it appears to be solution. It was thought that the pits might have been formed by the accumulation of a thin coating of silica around sand grains with comparatively flat surfaces juxtaposed, so that deposition of silica would go on around the grains but would not materially affect the flat surfaces. The frosted floors of the pits seemed to lend strength to this view. However, thin sections of pitted grains failed to reveal evidence of any secondary deposition around the sand grain. To all appearances the frosting of the surfaces of the sand grains is exclusively a superficial phenomenon. There has been deposition of secondary silica in the St. Peter sand locally, but the tendency is to reconstruct the grains so as to form crystals or crystal terminations. The idea of solution as the cause for this pitting therefore seems to be more tenable. It is probable that these pits seem more common on the larger sand grains simply because their greater size makes them more evident. Solution was apparently differential in its action, for not all large grains have pits. It may be that the etching or dissolving solution acted principally on the surface of the grains in the vicinity of the point of emergence of the crystallographic or vertical axis, along which solution of quartz is said to take place most readily, and that pits or scars were well developed only where contact of this axis and some other flat-surfaced grain occurred.[6] Apparently the formation of pits in the sand grains did not take place entirely while the sand was a part of the St. Peter sandstone, for numerous grains show pits which are rounded off and do not have the general sharpness of rim seen in the pits clearly of St. Peter age.

The frosting of the floors of the pits raises a question not only as to its own origin but as to the origin of the frosting of the St. Peter grains in general. If the frosting of the grains in general is due to solution which has taken place in the present deposit of sand, it would seem that the large and small grains alike should have frosted surfaces. However, it has been pointed out that most of the smaller grains are but slightly frosted and some not at all. It would appear, therefore, that either the solution which frosted the larger grains affected them at some other site of deposition than the present one and that they were transported to their present location in such a fashion that some of the grain aggregates stuck together, or the frosting is due to physical rather than chemical action. The evidence seems to favor the physical origin but the origin of the frosting of the floors of the pits, though probably due to etching, is not definitely known.

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[6] Dana, E. S., and Ford, W. E., A textbook of mineralogy, 3d edition, p. 191, New York, John Wiley & Sons, 1922.

PITS IN GRAINS WITH ADDITIONS OF SECONDARY SILICA

The addition of secondary silica to the grains of certain portions of the St. Peter has resulted in the formation of euhedral or partly euhedral grains. At the point of contact of any two given grains it is common to find pits whose shape is dependent principally on the shape of the grains at their point of contact. The bottoms of these pits are commonly frosted like other frosted St. Peter grains. This type of pit is thought to have been formed by the aggregation of secondary silica about grains in mutual contact but not at the points of contiguity. The frosted surfaces of the floors of the pits are thought to be the frosted surfaces of the original grains. This contention is borne out by thin-section studies of grains showing pits due to secondary deposition of silica.

SECONDARY ENLARGEMENT

In general, enlargement of the grains of the St. Peter by the addition of secondary silica is common in outcrops and in sand from wells reaching the St. Peter except in the Ottawa-Utica district where this phenomenon is restricted primarily to weathered deposits. The best examples of this phenomenon were noted in the sand of Calhoun County and in some of the outcrops in the Oregon district, particularly one isolated outcrop of very red sandstone in the SW. ¼ NE. ¼ sec. 8, T. 23 N., R. 10 E., about a quarter of a mile northeast of the quarry of the National Silica Company. The sand in Calhoun County contains grains which have been added to until they are about euhedral as well as many small and perfect crystals of quartz which do not appear to be secondarily enlarged quartz grains. Pitting is common in the larger grains.

In the locality near Oregon the grains are larger and the amount of silica added greater than in Calhoun County. Most of the grains are euhedral and pitted. The deposit is very red as a result of the presence of iron oxide. The secondary silica added to the grains is stained with the iron oxide whereas the original grain is free from this coloring material, and thus there is a very sharp line of demarcation between the original grain and the added deposit.

NUMBER OF GRAINS

It is obvious that a sieve analysis expressed in per cent by weight does not give information as to the number of grains retained on each sieve except in a general way. Certain uses of the St. Peter demand a sand which consists essentially of fine sand, others a coarse sand. If, therefore, analysis in per cent by number of grains were available, sand might be selected more intelligently and purchased more economically. Aside from the economic value of knowing the number of grains indicated in a sieve analysis by weight, these same data are scientifically interesting because they throw light on conditions of sedimentation and the physical structure of the St. Peter.

A scrutiny of the table of analyses by number of grains (Table 11, p. 150) shows that there is a wide variation in the composition of the sand at the various quarries but suggests that in general the quarries located near Ottawa and therefore in the upper part of the St. Peter have somewhat larger per cents of the coarser sand than do those near Utica, located in the middle and upper middle St. Peter.

Limestone and Dolomite in the St. Peter Sandstone

In his report on the St. Peter sandstone Dake[7] shows that in general the St. Peter of Canada, Minnesota, and Wisconsin is free from calcarerous or dolomitic beds. In Illinois and Iowa calcarerous beds are present, in Missouri one rather persistent limestone, and in Arkansas and Oklahoma generally two persistent limestone beds.

The limestone or dolomitic beds occurring in Illinois are known principally from well logs. In the Ottawa district, the approximate middle portion of the formation contains beds of shaly or thin-bedded sandstone locally called by the quarrymen "magnesia beds." Samples of these beds contained no magnesium carbonate, though back from the outcrop where weathering and solution have not been so active these beds may contain that compound. The calcarerous St. Peter in Calhoun County and near Shirland has already been mentioned. However, no calcarerous material comparable to that recorded in well logs in Illinois was noted in outcrops of the sandstone.

The most reliable data on the presence of limestone or dolomite in the Illinois St. Peter are the records of wells at Grays Lake and Lake Forest in Lake County. Samples were obtained from these wells and from them the St. Peter is known to consist of 20 feet of dolomite overlain by 30 feet of sandstone and underlain by 150 feet of sandstone at the former place and at the latter of 20 feet of dolomite overlain and underlain by 35 and 90 feet of sandstone respectively. At Area (Mundelein) in the same county the upper 50 feet of the sandstone is said to be calcarerous. At Mt. Carmel cemetery in Cook County the St. Peter is 120 feet thick and the upper 40 feet is reported as calcarerous. In the wells in Chicago and vicinity calcarerous or dolomitic sandstone is described in the upper St. Peter with a thickness varying from 20 to 55 feet. At Quincy in Adams County a well records 23 feet of limestone overlain by 11 feet of sandstone and underlain by 96 feet of sandstone.

From the foregoing data it seems that dolomite or limestone beds are present locally in the upper part of the St. Peter in Illinois, but their occurrence suggests that the beds are lenticular. The presence of calcarerous or dolomitic sandstone at the top of the St. Peter locally also seems fairly well established though the possibility that the carbonates were carried down the

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[7] Dake, C. L., The problem of the St. Peter sandstone: Univ. of Missouri School of Mines and Metallurgy Bull., technical series, vol. 6, No. 1, chapter I, 1921.

drill hole from the overlying limestone and dolomites should be given consideration.

CLAY IN THE ST. PETER SANDSTONE

CHARACTER

In general the clay of the St. Peter after removal from the sand and concentration in sufficient quantity to have an individual color, is cream white, varying to light or medium yellow. It is very sticky and plastic. When wetted and allowed to dry it forms a comparatively hard and brittle mass. The analyses in Table 1 show the chemical compositions of four typical clays.

TABLE 1.—*Chemical analyses of St. Peter clays*[a]

	United States Silica Company	Higby-Reynolds Silica Company (Reynolds west quarry)	Ballou White Sand Company	National Silica Company
	3.7 per cent clay	1.65 per cent clay	2.6 per cent clay	1.33 per cent clay
Lab. No	15366	15367	15368	15369
Identification No	13	38-39	47	51
SiO_2	48.88	47.42	48.92	53.58
Fe_2O_3	2.28	2.32	1.28	2.93
Al_2O_3	33.43	35.01	33.71	29.86
CaO	1.56	1.26	1.08	.76
MgO	1.06	1.18	1.06	.87
K_2O	.78	.94	.88	.96
Na_2O	.04	.32	.04	.04
SO_3	.34	.36	.34	.18
Loss on ignition	13.23	13.20	13.18	11.84
Total	101.60	102.01	100.49	101.02

[a] Date reported June 2, 1926; analyst J. M. Lindgren

OCCURRENCE

The clay of the St. Peter occurs principally as an interstitial filling between, and as a coating on the sand grains. Locally in certain zones or beds, commonly not over 5 feet thick, the clay content is greater than elsewhere, but no distinct clayey beds or layers were noted in the formation.

DISTRIBUTION

From a study of the results of the tests for clay shown in Table 10, p. 148, certain very interesting data are brought forth. If the amount of clay is plotted on a map it becomes apparent that the outcrops in the Ottawa-Utica district may be divided into three groups on the basis of clay content. The outcrops in the first group are east of a line running north-south through the centers of secs. 9 and 16, T. 33 N., R. 3 E. They have a low clay content, varying from 0.72 to 1.60 per cent and averaging 1.11 per cent. The second group lies west of the east line of sec. 14, T. 33 N., R. 2 E., and has a medium clay content ranging from 1.8 to 3.10 per cent and averaging 2.366 per cent. The third group, the one having the high clay content, lies between the other two geographically. The amount of clay present varies from 2.20 to 4.70 per cent and averages 3.36 per cent. Although these divisions are more or less arbitrary they conform in a general way to the distribution of the three kinds of overburden on the underlying sandstone.

In the area of low clay content, the sandstone has a very slight overburden consisting of river silt and locally of limited areas of Platteville-Galena limestone as in the quarry of the Standard Silica Company (plant No. 2) where the clay content is highest for this division. The sand quarries in this area are located in the Ottawa platform. The unit having the medium clay content is in the area near Utica where Pennsylvania strata are absent from the top of the sandstone and are replaced by glacial drift as the material superadjacent to the sandstone. The area of high clay content is that covered by the Pennsylvanian clays and shale, which are in turn overlain by glacial drift.

ORIGIN

Three theories for the origin of the St. Peter clay suggest themselves: (1) that the clay is primary; (2) that the clay is secondary; and (3) that some of the clay is secondary and some primary. The primary origin implies that the clay was deposited at the same time as the sand itself, the secondary origin that it has been introduced into the sandstone since its deposition, and the combination of primary and secondary origin that the clay as now found is the result of both modes of accumulation.

One of the most striking things shown by the table of chemical analyses of the St. Peter clays (page 51) is the similarity of the analyses. The samples tested were selected to represent the St. Peter in various regions where it outcrops and is worked commercially and are therefore widely spaced as shown by the map of the St. Peter outcrops (Pl. I, p. 14). They also represent different parts of the formation vertically. If the clays were secondarily introduced into the sandstone it would seem logical to expect a difference in the character of the clay in different geographic areas. The fact that the clays are so very nearly alike as to chemical analysis, areally and with respect to the formation as a whole, suggests that they have been introduced into the sandstone by some agency capable of depositing clay of the same sort at about the same time over a wide area. This requirement seems to be satisfied by the primary deposition, in the St. Peter sea, of clay derived from essentially the same source throughout St. Peter time. The freedom of the sandstone from beds of clay show that the St. Peter sea was clear and that the comparatively small amount of clay deposited was probably mechanically entrapped during the deposition of the sand.

According to the foregoing statement the St. Peter should contain about the same amount of clay throughout its areal extent. It has been pointed out, however, that this is not the case, and in this connection should be noted the distinct relation between the perviousness of the overburden to ground water and the clay content of the sandstone above ground-water level. Where the overburden is Pennsylvanian clay and shale, the clay content of the sandstone is the highest, presumably because these beds are highly impervious to water and therefore do not permit the ready entrance of water into the sandstone, thereby defeating downward concentration of the interstitial clay to a zone at or below the ground-water level. Where the overburden is a thin covering of silt the entrance of ground water is not greatly hindered and downward concentration of clay is readily accomplished. The permeability of glacial drift would be intermediate between that of the Pennsylvanian beds and that of silt. Fluctuations of the level of ground water might also cause downward concentration of the clay.

Downward concentration of materials by ground water is evidenced by the bands containing organic material found in a number of the quarries in the Ottawa platform, especially in the quarry of the Standard Silica Company. These materials have been carried to a depth of at least 12 feet since Illinois River ceased to erode actively the rock terraces in its valley and since organic material became an important constituent of the soil overlying the sandstone in these terraces. Another phenomenon thought to indicate concentration of clay by ground water is the commonly joint occurrence of high clay and high iron content in the same bed of sandstone. In the quarries which reach the depth of ground-water level it is very common to find the bottom beds much higher in clay than those well above water level. These former beds are often termed "magnesia" layers, because of the high percentage of fine sand and clay they contain.

The chief argument for the secondary origin of the clay of the St. Peter is its distribution in the fashion which would be expected from the transportation of clay by descending ground water and its concentration in zones at or just above temporary ground-water tables. The absence of conspicuous beds of clay also argues for this origin. What most seriously opposes secondary origin of the clays is that if they came from the overburden as it is today, they should not, and probably would not, have the similar chemical compositions which the analyses indicate, unless practically all of the clay came into the sandstone from the Pennsylvanian strata before erosion removed parts of them. The imperviousness of the fire clay and shales on the sandstone suggests that no great amount of ground water would permeate them at one time, but over a long period of time it is possible that sufficient clay might be carried down from the fire clay to give the sandstone its present clay content. This would not, however, account for the similarity of the clay of the Oregon-Dixon area, where the overburden is limestone or drift, to the clay of the La Salle area.

It would seem that to account completely for the clay in the St. Peter a combination of primary and secondary origins should be postulated. However, it is thought that the bulk of the clay in the formation is probably primary, but that its composition and distribution have been modified by secondary additions and by re-distribution.

Iron in the St. Peter Sandstone

In general, the amount of iron contained by the St. Peter sandstone is relatively low (Table 2). Some very red and decidedly green sands have been analyzed and found to contain only one-half of one per cent of iron oxide (Fe_2O_3). The deepest yellow sand obtainable contained less than 0.3 per cent iron oxide. These analyses do not include the amount of iron in the ramifying, vein-like bands of red iron oxide and silica which occur locally in the sandstone. Iron, ~~a~~occurring principally as the sulphide, is present in smaller amounts in the white sandstone than in the colored sand. The total impurities in the white sand rarely exceed three per cent and are chiefly clay.

OCCURRENCE

Except where disseminated as marcasite masses and marcasite vein fillings, the iron compounds in the St. Peter occur as a coating on the sand grains, or as a constituent of the interstitial clay or in both ways. In this bulletin the term "iron bands" is used for convenience but with the specific understanding that such bands are simply zones in the sandstone in which iron compounds occur as a coating on the sand or as interstitial material. Of the yellow, red, and green iron oxides, the last two are comparatively uncommon. Green sand was found near Rockford and Oregon, associated with the upper and basal beds of the formation. The largest exposure of green sandstone noted was at Green Rock in NW. ¼ sec. 11, T. 22 N., R. 10 E., where about 20 feet of interbedded green and white sand is exposed. The only observed extensive bodies of sand colored by the red oxides were found near Oregon and in Calhoun County. Elsewhere the red sand is found as part of the cement-forming, ramifying, vein-like bands through the sandstone or as local

TABLE 2.—*Iron in the St. Peter sandstone*

Sample No.	Quarry or outcrop	Per cent iron oxide (Fe_2O_3)
A	Red St. Peter sand	.51
B	Green St. Peter sand	.51
11	Ottawa Silica Molding Sand Company	.30
14	Benson Richards Sand Company	.34
21	Wedron Silica Company	.20
24	National Plate Glass Company (new pit)	.32
25	Bellrose Sand Company	.31
26	Illinois Valley Silica Company	.35
27	Standard Silica Company	.27
33	Standard Silica Company (Plant No. 3)	.15
34	Federal Silica Mines	.23
35	Federal Silica Mines	.25
38	Higby-Reynolds Silica Company (Reynolds west quarry)	.12
40	American Silica Sand Company	.22
42	Rock Island Sand Company	.43
45	South Ottawa Sand Company	.10
51	National Silica Company	.09

irregular masses which give the exposures of the sandstone a blotchy appearance. The yellow oxide is by far the most common. It occurs in four principal ways:

(1) As more or less regular bands from a fraction of an inch to about a foot thick. In some places the oxide is found in porous beds of sandstone which are underlain by beds containing a high percentage of very fine sand. In other places these bands are found in homogeneous beds without any fixed vertical position with reference to the beds as a whole. Screen analyses of the sand above and below these bands and of the sand composing them show practically no difference in texture.

(2) As irregular, ramifying bands. These occur along joint planes and also in homogeneous beds of sandstone which they penetrate at random. Sieve analyses of the sand adjacent to and composing these bands show no significant difference in texture.

(3) As concentric bands from ⅛ to ¾ inch thick around a center of sand held together by pyrite, of sand held together by a deposit of very brown iron oxide, or of pure white sand. The resulting mass of iron-cemented sand is roughly spherical and concretionary. These spherical masses occur in zones, most commonly in beds of medium or coarse sand, and also along joint faces. Few of the entire nodules are over 4 inches in diameter; they are commonly between 1½ and 2 inches in diameter.

(4) As irregular masses ranging in size from about ⅛ inch to several feet. In places the sandstone is literally peppered with the smaller deposits of the yellow oxide.

The iron sulphide in the St. Peter occurs as both marcasite and pyrite, though the former predominates, in three principal ways:

(1) As disseminated interstitial masses. These are most commonly found in strata of medium or coarse sand, and occur in zones and in deposits distributed through what are probably individual beds. The disseminated marcasite is found almost exclusively in that part of the St. Peter which constitutes the rock terraces of Illinois and Fox rivers. In one outcrop attenuated rows of interstitial marcasite grains were noted following the cross-bedding of the sandstone.

(2) As a cement binding sand together in the form of nodules. These marcasite-sand nodules are commonly round and vary from ⅛ inch to 3 inches in diameter. Some are surrounded by concentric bands of brown and yellow sand, and others are sharply defined from the sand matrix without any discoloration at the periphery.

(3) As a joint filling. The best type of this occurrence of marcasite was noted at Wedron where the removal of the sandstone from one side of a joint had left the filling as a scale about ¼ inch thick over the lower 20 feet of a 65-foot face with a linear extent of about 50 feet (fig. 6).

ORIGIN

As stated, all the iron minerals so far described occur not as individual grains but as an interstitial filling or as a coating on sand grains. They cannot, therefore, be considered primary in the same sense as the zircon, rutile, and tourmaline found with the sand, but may represent iron deposited contemporaneously with the accumulation of the St. Peter sand. The only iron-bearing mineral noted in the St. Peter which is certainly primary is black tourmaline. The number of grains of this mineral is proportionately very small and as the grains show no evidence of solution, they do not seem likely sources for any considerable amount of secondary iron in the sandstone.

It is thought that the present deposition by springs of hydrated iron oxides in the St. Peter sandstone and the occurrence of joint fillings of marcasite, obviously deposited by ground waters, together with the lack of any consistent relation between the iron present and stratification, and the absence of horizontal deposits of the marcasite, seem to favor the secondary origin of the iron in the St. Peter.

SOURCE AND MODE OF ACCUMULATION

In this discussion remarks will be confined chiefly to the Ottawa-Utica area in northern Illinois because this region contains the most extensive exposures of the St. Peter in the State. It is thought, however, that the origin of the iron in this region, if correctly ascribed, should give a key to the origin of the iron elsewhere, modified perhaps by local conditions.

In the rock terrace near Ottawa the iron in the sandstone occurs principally as interstitial marcasite and as limonite mixed with the interstitial clay. The discloration of the sandstone is, in general, slight. The overburden is commonly either river alluvium or Platteville-Galena limestone. From Ottawa west for about 4½ miles the sand quarried for molding sand from the river bluffs is strikingly yellow, especially in the upper portion of the exposures. The iron occurs principally as limonite in horizontal and ramifying bands and also as small blotches speckling the sandstone. Interstitial marcasite is also present usually associated with annular deposits of yellow oxides around the marcasite centers. The overburden on this sandstone consists in ascending order of fire clay—commonly containing marcasite or pyrite nodules and concretions—coal, shale and glacial drift. Near Utica the sandstone taken as a whole is buff colored, though in the upper part of the exposures yellow bands of sand are common. Interstitial marcasite is relatively common with yellow bands surrounding the marcasite core. The overburden consists of glacial drift.

There are, therefore, three different types of sand in this Ottawa-Utica district, the white (or nearly white), the yellow, and the buff, and each type has a different overburden. The topographic position of the yellow and buff sands is the same. The deposits in the rock terrace near Ottawa are topographically lower than those in the bluff. It seems reasonable to conclude, therefore, that the overburden has been to a large extent the source of the iron contained in the sandstone and that the variation in the intensity of the coloration caused by the iron hydroxide, or the amount of the oxide present, reflects, more or less directly, the amount of ferruginous material available to ground water in the overburden. In all three types of sand the amount of marcasite present is thought to be about the same, but in the quarries in the rock terrace near Ottawa, the oxidation of the marcasite to the yellow oxide is much less marked than in the molding sand quarries in the bluff farther west.

Inasmuch as springs issuing from the St. Peter in the base of some of the pit quarries which have been deepened to ground-water level, are depositing iron hydroxide and producing regular bands of yellow sand as well as irregular limonite-stained masses in the sand at or near ground-water level, it seems logical to conclude that this type of deposition may be responsible for the bands and irregularly stained sand masses where they are colored by limonite. The fluctuation in the water table and the causes thereof are a problem in themselves, but it may be suggested that such fluctuations were related to variations in the volume of water carried by Illinois River during glacial, interglacial, and post-glacial times.

The marcasite with its associated annular deposits of yellow oxides admits of three possible modes of origin: (1) The marcasite is primary, and the rings of yellow oxide surrounding it are the result of its oxidation; (2) the marcasite is secondary and the yellow rings around the central mass are due to its oxidation; (3) the core has been formed by the reduction of the annular yellow oxide and the inward concentration of the reduced product.

The first mode of origin is self-explanatory. If the second mode of origin was the case the marcasite has probably been precipitated from solutions in the sandstone and hydrogen sulphide which is common in some waters of the St. Peter may be responsible for the precipitation. If the third mode of origin was the case it seems that the process of forming iron sulphide from the yellow oxide has not been active for some time except perhaps locally, for the St. Peter sandstone, especially in the Illinois River bluff, has probably been above ground-water level and subject to oxidation most of the time since the Wisconsin glaciation.

The data available seem to favor the second mode of origin.

Concerning the ramifying bands of red and yellow iron oxides which penetrate the sandstone, in many places, it is tentatively suggested that these bands may represent the course of solutions descending from concentrating areas such as depressions or basins in the top of the sandstone, or similar areas in the top of a relatively impervious bed in the sandstone overlain by a porous stratum. This condition of maximum iron content below depressions in the top of the sandstone was strikingly shown in the quarry at Oregon. If these downward-moving waters were charged with iron oxides in suspension as finely divided solids or colloids, they might follow an irregular course through the sandstone; the course would be influenced by minor differences in the porosity of the sand caused by the size of the sand grains or by the amount of interstitial clay present. As a result of retarded circulation the waters would leave along the edge of their zone of descent a coating of iron oxide which would serve to delimit the margin and circumscribe the width of the band. In the center the movement of the water would keep the channel clean for a time. As the channels become filled or clogged by deposits of iron from the water, the descending fluid would be forced to back up or break through the surrounding deposit and seek new ways of descent. Repeated clogging of a delimited path of descent and the development of new paths together with variations in the porosity of the sandstone may be the key to an explanation of this phenomenon.

Heavy Minerals in the St. Peter Sandstone

In view of its high quartz content and the amount of clay present, it is obvious that the St. Peter cannot contain very large amounts of heavy minerals. Separation of the heavy minerals from the quartz sand has commonly been effected by the use of liquids of such gravity as to float the quartz and allow the other, heavier constituents to sink. In view of the inadaptability of this method to handling of large quantities of sand and obtaining representative collections of heavy minerals from the St. Peter sand, samples of about 20 pounds each were run over a Wilfley jig table so regulated as to give a separation of the quartz sand and the minerals of greater specific gravity.[8] Each sample was run over the table three times and the crop from the table further concentrated in bromoform.

As Table 3 shows, the principal heavy minerals occurring in the St. Peter sandstone are zircon, tourmaline, anatase (octahedrite), and, in lesser amounts, pyrite, marcasite, limonite, spinel, and garnet.

Zircon is the most common heavy mineral present. The grains vary greatly in size and range from very minute to comparatively large grains about a millimeter in maximum dimension. Most of the grains are of the elongate rather than of the stumpy type, and are, almost without exception, rounded. Some are so rounded as to be roughly cylindrical in shape; others are less rounded and the original larger faces are still recognizable. Most of the larger grains contain inclusions. The grains are in general white, though a few very light pink and yellow grains were noted.

The tourmaline grains are in general very well rounded; some of the black grains are nearly spherical. There are, however, a few euhedral grains, mostly yellow or brown. Black and brown tourmaline is by far the most common. Yellow, purplish-brown, reddish-brown, and orange-red grains are, however, not uncommon and there are also a few green and blue grains.

The anatase occurs mainly as flat, tabular, octahedral, orange or yellow grains. The grains are euhedral and show no signs of wear other than breakage by fracturing.

The marcasite and pyrite occur chiefly as remnants of interstitial materials. There are, however, a number of octahedrons and cubes of pyrite and crystalline aggregates of marcasite. The limonite occurs in the same general shape and form as the iron minerals already mentioned and much of it preserves the crystal form of the mineral after which it is a pseudomorph.

The spinel grains are well rounded and green. They are probably ceylonite. The few garnets noted were light green and rounded. The mineral thought to be epidote was angular.

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[8] The author is indebted to Professor A. E. Drucker of the Dept. of Mining Engineering of the University of Illinois for his assistance and cooperation in this separation.

TABLE 3.—*Heavy mineral content of the St. Peter sandstone*

Sample No.	Estimated per cent of major constituents			Spinel	Garnet	Epidote (?)	Pyrite	Marcasite	Limonite	Grams of heavy minerals in 10 lbs. of St. Peter sand
	Zircon	Tourmaline	Anatase (octahedrite)							
1	45	45	10		R	R	R			0.07
8	55	45	R	R			C			1.62
9	55	45	R				*	*	A	1.26
11	50	50	R					*	R	1.51
13	65	35	R					C*	C	1.27
18	45	55	C	R				C		1.33
25	65	35	R	R				R		3.19
33	50	50	R							2.40
36	80	20	R	R						2.60
43	50	45	5	R			C*	C*	C	1.14
45	50	50	R	R			R*	*	R	0.95
47	70	30	R	R						2.78
51	35	30	35							3.60
54	50	50	R	R			R*	*	R	1.93
60-61	30	70	R				R*	*	R	0.18

R—rare C—common A—abundant

The asterisks in the pyrite and marcasite columns indicate from which of the two minerals the limonite has probably been derived.

In addition to the above mentioned minerals there are a number of grains which are translucent or opaque, white, gray, brown, red or yellow, but which were not definitely identified. All have very smooth and shiny surfaces in contrast with the frosted surfaces of the other grains. It is thought that the white and gray grains are probably chalcedony, chert or agate. The other grains are very easily crushed to a powder and are thought to be masses of clay with a ferruginous cement.

The surfaces of the tourmaline, zircon, spinel and garnet grains are in general frosted. The frosting is usually similar to that on the St. Peter grains, but the surfaces of some of the grains are covered with minute chip marks. Some of the tourmaline grains show irregular pits and grooves, through which the unfrosted mineral shows very clearly. It is also not uncommon to find some of the black tourmaline grains with one side beveled to a very flat, even surface.

Aside from the minerals listed, mica was noted in the basal St. Peter in the Oregon-Dixon area. Because of its flaky character, any of this mineral which might be present in the samples would be lost during the concentration on the Wilfley table.

The size of the heavy mineral grains is shown in Table 4. In general the heavy grains are small compared with the quartz grains composing the St. Peter sand. It is also of interest that, comparatively, the tourmaline grains are the largest, the zircon grains of medium size, and the anatase grains smallest.

Table 4.—*Size of heavy mineral grains*

Sieves		Sieve openings Millimeters		Per cent retained	Mineralogical composition of sand retained [a]
Thr'gh	On				
48	65	.295	.208	0.4	Principally black and brown tourmaline
65	100	.208	.147	11.7	Black and brown tourmaline about 90 per cent, zircon about 10 per cent
100	150	.147	.104	18.0	Principally tourmaline and zircon in about equal amounts, and spinel in minor amounts
150	200	.104	.074	26.6	Zircon about 70 per cent, tourmaline about 30 per cent, minor amounts of spinel
200	270	.074	.053	19.0	Zircon about 85 per cent, tourmaline about 10 per cent, anatase about 5 per cent
Pan		Less than .053		24.3	Zircon about 85 per cent, tourmaline about 10 per cent, anatase about 5 per cent

[a] Pyrite, marcasite and limonite in minor amounts are present in all the samples, though principally in the larger sieve sizes.

Of the grains identified from the St. Peter the zircon, tourmaline, garnet, spinel, and epidote are thought to be primary. The pyrite, marcasite, limonite, and anatase are thought to be secondary.

The weights of heavy mineral grains present in the samples are shown in Table 3. These figures are influenced to some extent by the differences in specific gravity of the predominant minerals, but they give approximately the quantity of heavy grains present in a unit weight of sand. It is of interest that the samples of sand from quarries in the rock terrace near Ottawa, Samples 1, 8, 9, 13, 43, and 45, are comparatively low in heavy-mineral content, whereas the samples from the Illinois River bluff west of Twin Bluffs, Nos. 25, 33, and 36, are comparatively high. Sample 11 from Buffalo Rock is an exception to these general relations, for it has a low mineral content although it would normally be expected to resemble the river bluff samples rather than the rock terrace samples in this respect. Sample 18 from Wedron coincides with the samples from the rock terrace. The differences in the heavy-mineral content are thought to be due to horizontal rather than vertical variations in the quantity of the minerals present.

CHAPTER IV—THE QUARRYING AND PREPARATION OF ST. PETER SAND

Introduction

The various grades of St. Peter sand produced commercially in Illinois may be combined into two principal groups, washed sand and crude sand. As the name implies, the former is washed before it is sold, and its quarrying and preparation is a very different process from that employed with the crude sand which is commonly sold without preparation other than crushing. The quarrying and preparation of these two classes of sand will, therefore, be discussed separately.

Washed Sand

GENERAL STATEMENT

Washed St. Peter sand has a multiplicity of uses which are described in Chapter V. This type of sand is often spoken of as glass sand, because large amounts of it are sold for making high-grade glass. It also finds wide use as sand-blast sand, filter sand, engine sand, and grinding and polishing sand. In fact, whenever a silica sand of highest purity is desired, the St. Peter may be used.

In general only sand which is initially freer from iron than the crude sand sold for steel molding is washed because, though the clay can be removed during the washing process, the iron coating the sand grains is much more difficult to eliminate.

The quarries producing washed sand are located with a few exceptions in terraces along the Illinois or Fox rivers. The Ottawa, Standard (Plants 1 and 2), and United States Silica Companies are located in the Ottawa terrace, a rock terrace in the valley of Illinois River. The Wedron Silica Company and Ballou White Sand Company are located in rock terraces along the Fox. The two remaining quarries, Higby-Reynolds and the National Silica Companies, are located respectively in the bluff of Illinois River and in a rock hill not related to any large stream.

TYPES OF QUARRIES

There are two principal types of quarries from which washed sand is produced, namely pit and bluff quarries. Quarries of the first type are those which have been sunk in a comparatively level original surface. The bluff quarries are those which have been developed by working back into a bluff or

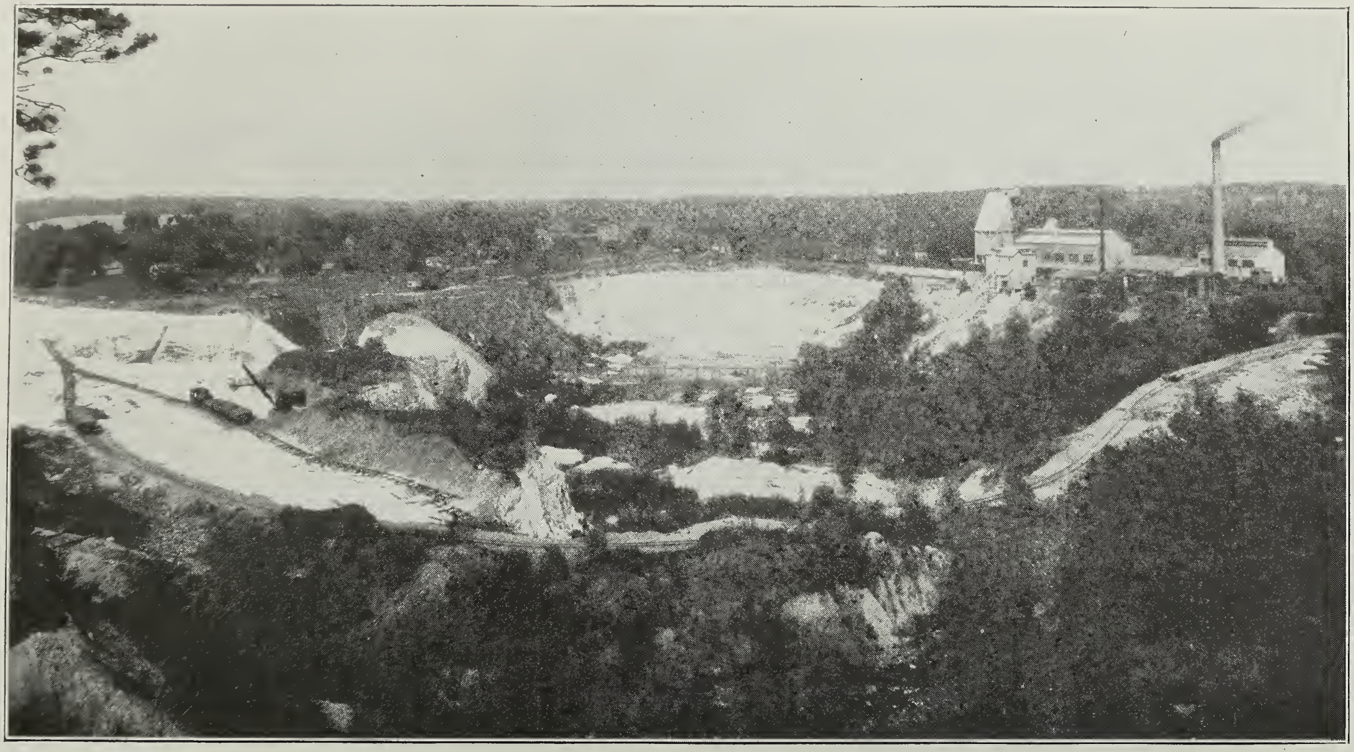


Fig. 18. Quarry and plant of the Wedron Silica Company. At the left of the picture may be seen one of the openings, an area of stripped sandstone, and the gasoline shovel removing the overburden. In the center of the foreground is the dump for the overburden. In the center of the picture is another opening. At the right is the plant. The tall building is the screen house. (Photograph by courtesy of Wedron Silica Company.)

cliff of rock. The majority of the washed sand quarries are pit quarries (figs. 18 and 19).

OVERBURDEN AND ITS REMOVAL

In most quarries the overburden on the sandstone quarried for washed sand is unconsolidated material, silt, sand, gravel or glacial drift. The average thickness varies from 6 inches to 10 feet. At the quarries of the United States Silica Company and Standard Silica Company (plant No. 2), however, there are local areas in which a few feet of Platteville-Galena limestone lies above the sandstone, but these are generally avoided.

The methods of removing overburden vary according to the amount of material to be removed and the personal preferences of the operators. In general the bulk of the overburden is loaded by steam shovels into auto trucks, wagons or dump cars which remove it to some convenient place of disposal (fig. 20). The overburden at some quarries is dumped into a worked-out portion of the quarry or into an adjoining gully. In others having a very thin overburden, it is scraped back from the working face with a drag-line scraper until sufficiently large piles have accumulated to warrant larger scale operations for their removal. After the bulk of the overburden has been removed the depressions in the surface of the sandstone are commonly cleaned out by teams and scrapers and finally by men with shovels. The top of the sandstone is then thoroughly swept with stiff brushes and a final cleaning of any pockets or holes effected with compressed air or steam. Thus the impurities from the

Fig. 19. Quarry of Plant B, Ottawa Silica Company. Note stripped area at right of picture and quarry of Plant A in left background.

overburden which might enter the sand when it is quarried are reduced to a minimum.

BLASTING

In order to quarry the sandstone most efficiently by hydraulic methods, it is necessary to loosen it by blasting. Several schemes are employed, one of which is to drill vertical holes 5 to 10 feet deep, 8 or 10 feet from the quarry face and spaced 6 to 8 feet apart, which are loaded with dynamite. The explosion of the dynamite loosens the sand. Another method consists of drilling holes horizontally into the face at its base. These holes are sprung with a light shot, cleaned out and reloaded with a much larger charge, which effectively loosens the sand above when exploded. The term "gopher-holing" is applied to this mode of blasting. Water-jet tripod or hand drills are commonly used for drilling the blast holes. Most of the primary blasting is done in the fall and the sand allowed to weather and disintegrate during the winter, so that by spring a large part of the material has broken up into loose grains or slightly coherent masses. Sometimes after the upper loose sand has been quarried, a projecting toe or ledge of undisintegrated rock is uncovered at the base of the quarry face. A hole is commonly drilled horizontally into the base

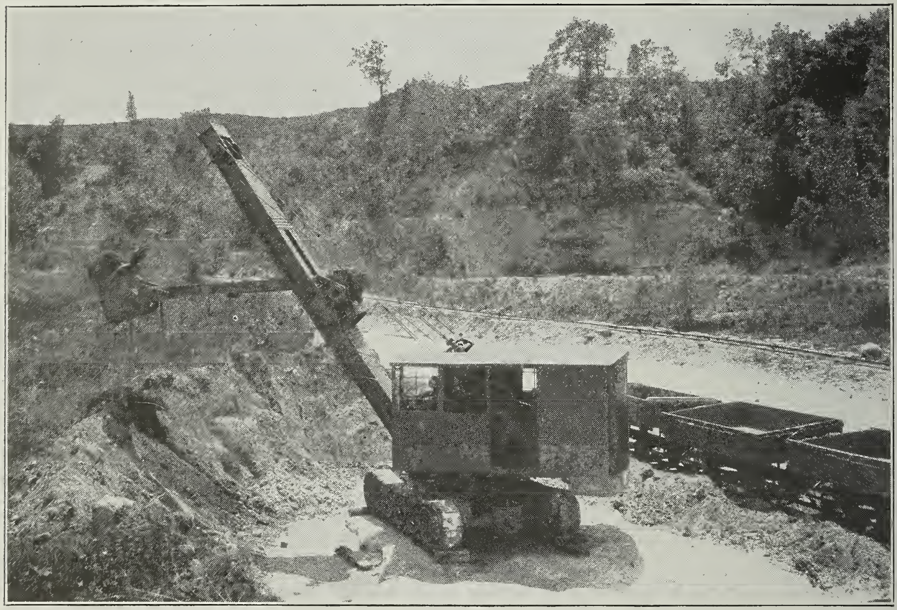


Fig. 20. Gasoline tractor shovel and side dump cars used for removing overburden at the quarry of the Wedron Silica Company. In the background is a cliff of St. Peter sandstone capped by glacial drift. (Photograph by courtesy of Wedron Silica Company.)

of this toe by means of a water-jet drill usually hand operated, and the toe broken up with a charge of dynamite. This same method is also employed to loosen and fragment slides or falls of large chunks of sandstone. Dobying or mud capping is commonly employed for breaking up large blocks of sandstone which have survived the other blasting.

HYDRAULIC QUARRYING

With the exception of the National Silica Company at Oregon, all the companies producing washed sand employ hydraulic methods in quarrying.

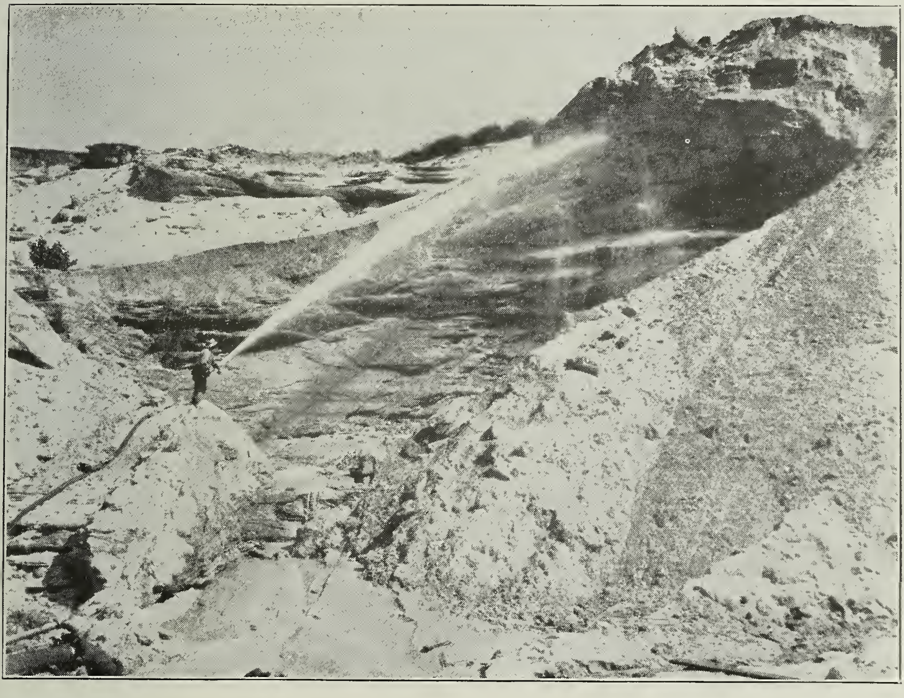


Fig. 21. Hydraulic quarrying of the St. Peter sand. The sump and pump are just beyond the left foreground of the picture. (Photograph by courtesy of Ottawa Silica Company.)

This method consists of directing a stream of water under 40 to 120 pounds pressure against the blasted and weathered sandstone as shown in figures 21 and 22. The sand and water flow away from the quarry face to a shallow depression or sump in the center of which is set a steam-operated sand pump (figs. 23 and 22). The intake of the pump has an iron grating over it which prevents lumps of sand larger than about ¾ inch from entering the pump. The lumps of sand which accumulate on the grating are periodically removed with a perforated shovel.

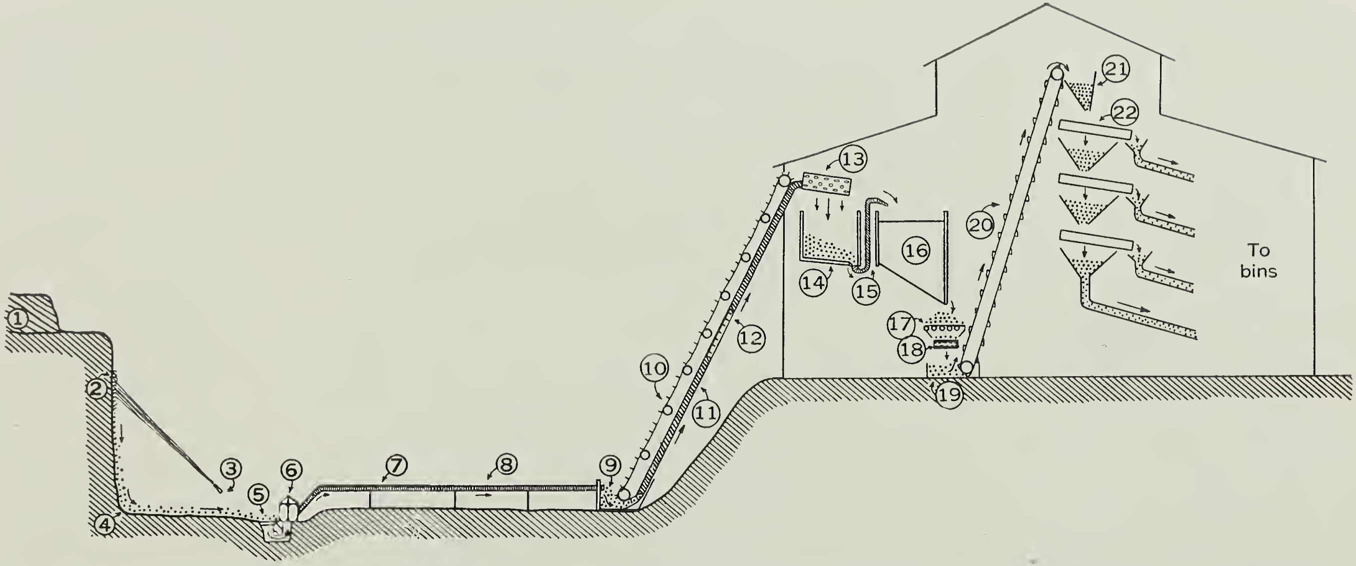


Fig. 22. Generalized diagrammatic flow sheet for washed St. Peter sand showing the progress of the sand from the quarry face to the storage bins.

(1) Overburden removed by steam shovels, teams and scrapers, brushing by hand and finally compressed air.
(2) Quarry face—loose sand.
(3) Hose, throwing stream of water under 40-100 pounds pressure.
(4) Sand and water run down quarry face to sump.
(5) Iron grate for screening out lumps of sandstone. Lumps removed by men with perforated shovels.
(6) Sand pump, steam or air operated.
(7) Iron pipe, conveying sand to elevator.
(8) Sand from different faces of the quarry, sometimes collected from different pipe lines and discharged into a gathering sump from which an auxiliary pump discharges it into a single large pipe line which conveys it to the elevator.
(9) Pipe line discharge.
(10) Drag-belt elevator or conveyor.
(11) Trough on which cleats on belt drag up the sand and water.
(12) Side of trough removed showing operation of cleats.
(13) Cylindrical scalping screen for removing lumps of sand, sticks and the like. Material not passing sieve is discarded.
(14) Washer. Strong jet of water directed on sand frees it from clay. Clay flows off and is discarded.
(15) Sand is pumped from washer to draining bins.
(16) Draining bins. Sand feeds by gravity to drier after it has drained
(17) Steam coil drier. When dry, the sand falls between coils to conveyor belt.
(18) Conveyor belt. Takes dried sand to bin.
(19) Bin. Sand feeds from bin to bucket belt elevator.
(20) Bucket belt elevator. Carries sand to top of screen house, dumps it into bin which distributes it to sieves.
(21) Bin.
(22) Sieves. Sand retained goes through wooden spout to storage bins. Sand passing sieves falls into collector and is spouted to another sieve.

The number of places in the quarry at which sand will be quarried depends on the quantity of sand it is desired to produce. As different portions of the face are worked back they become more or less individualized into separate rooms or openings (fig. 24). Converging to a common point from the face of each opening are a number of pipe lines so spaced at the face as to handle conveniently the sand to be quarried by simply moving the pump from one to the other of these pipes. As the face is quarried back such additional pipe lines as are necessary are added to the fan-shaped net work.

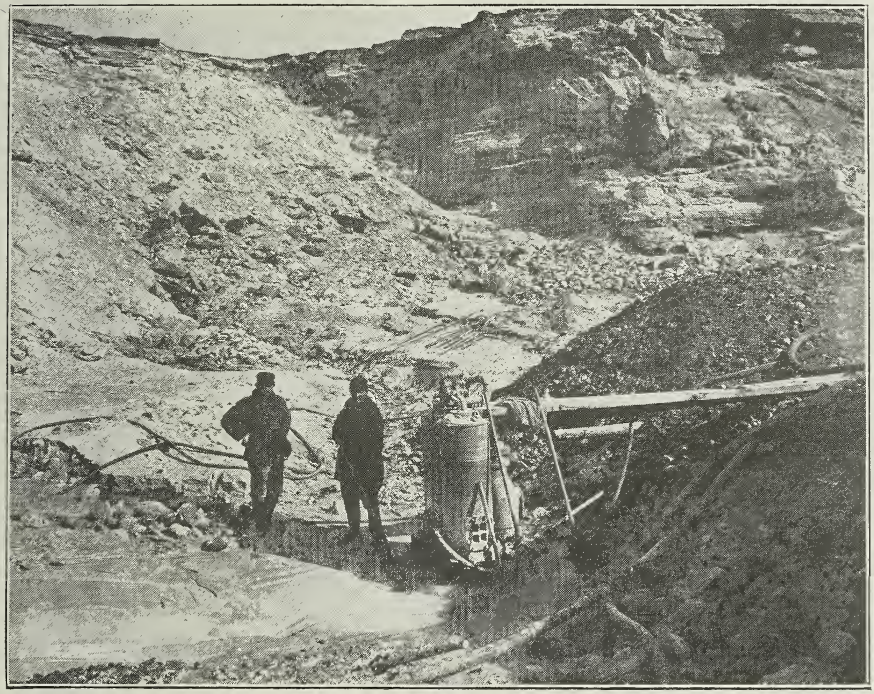


Fig. 23. Sand pump and sumps in quarry of the United States Silica Company. (Photograph by courtesy of the United States Silica Company.)

At the converging end of the pipe lines is a sump. When more than one stream of water and pump are in operation at the face, the sand is discharged into this sump (figs. 24 and 25). An auxiliary pump draws the sand from the sump and forces it into a single main pipe line which conveys the sand to the drag-belt elevator. In some quarries the gathering sump and auxiliary pump are omitted.

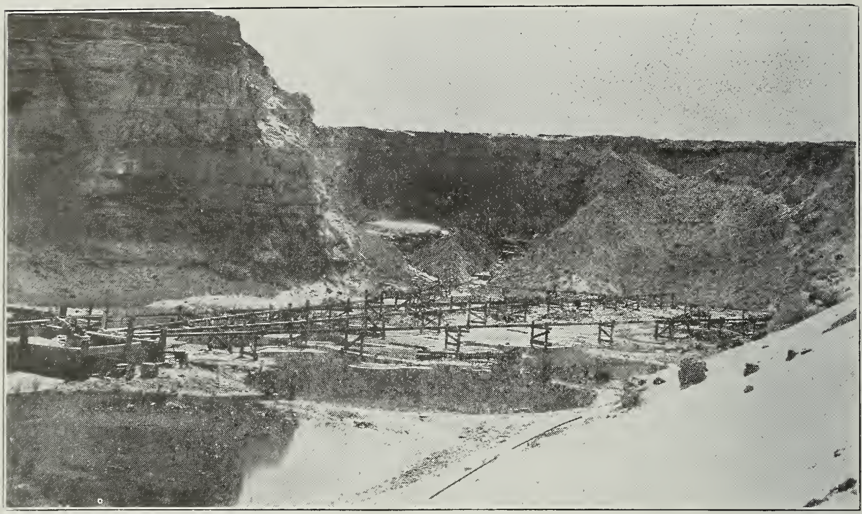


Fig. 24. Quarry of the Ottawa Silica Company. One of the openings is visible in the center of the picture. The picture also shows the arrangement of converging pipe lines from the working face to the gathering sump and auxiliary pump at the extreme left.

Fig. 25. Gathering sump in quarry of the Ottawa Silica Company.

ELEVATING THE SAND FROM THE QUARRY

The sand and water from the pipe line is discharged into a wooden box which surrounds the lower end of the drag-belt elevator or conveyor (fig. 22). This consists of a long rubber and fabric belt about 16 or 18 inches wide, to which are nailed wooden blocks or paddles about three inches high, two inches thick, and as wide as the belt. These are commonly "soled" with pieces of hardwood about an inch thick, fastened to the upper edge of the blocks. By replacing these hardwood soles it is possible to "re-sole" the conveyor without removing the paddles. In figure 26 this belt and the paddles are clearly shown. The portion of the belt which is descending, that is the part showing the paddles, rides on large pulleys. The rising part of the belt moves in a flume. As the paddles come around the lower terminal pulley of the belt mechanism, they dip into the sand and water in the box which surrounds the lower end of the belt, and drag with them some of the sand and water into the flume. The paddles and flume are proportioned so as to have the minimum

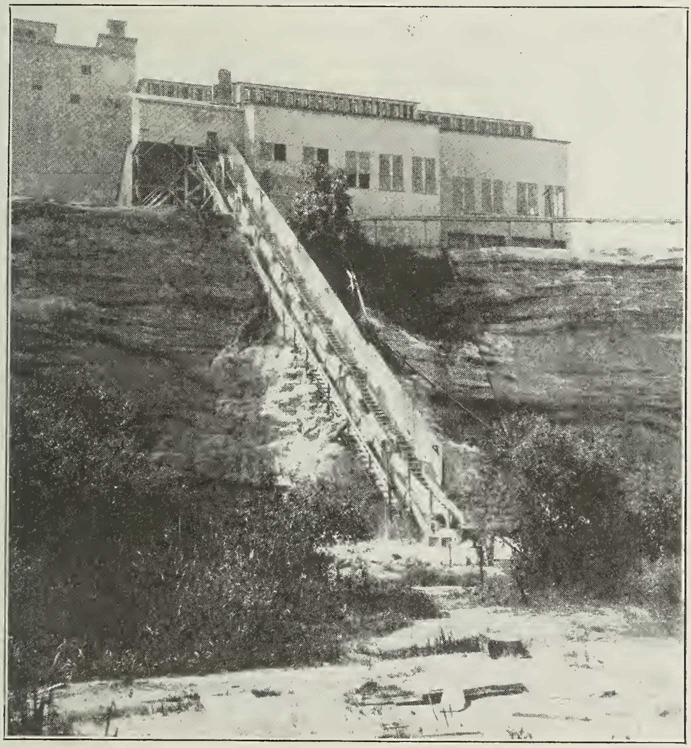


Fig. 26. Drag-belt elevator. (Photograph by courtesy of Ottawa Silica Company.)

practical working clearance, but some of the sand and water runs back down the flume from each paddle. It is caught by the succeeding paddle and carried up so that a practically continuous discharge of sand and water occurs at the upper end of the belt.

PRELIMINARY SCREENING

The sand and water from the elevator runs into a cylindrical screen, commonly known as the "scalping" screen. This screen has perforations of ⅛, ¼, or ½ inch according to the perference of the operator. For the finer openings square-holed wire screening is used. The screens with the larger openings are commonly perforated steel. As the cylindrical screen revolves, the sand and water passes through it into the washers. The material retained on the screen discharges from the lower end into a box or trough from which it is commonly disposed of by gravity to a waste heap. This material consists principally of lumps of sand held together by iron or a siliceous cement, or of lumps of marcasite.

WASHING THE SAND

A number of different types of washers are employed in producing washed sand. The most common type is a rectangular concrete tank about 12 feet long, 8 feet wide and 8 feet deep with a floor sloping toward the discharge end. The side of the tank at the discharge end has a vertical opening about a foot wide cut through the middle of the entire side, and each side of this opening or gate has a vertical slot of such size as to accommodate pieces of 2 by 4 inch lumber. As the sand enters the washer from the scalping screen a workman directs a strong stream of water from a hose on it. This serves to loosen any clay present and disintegrate any small lumps of sand which still persist. The wash water containing the clay in suspension flows out of the gate at the end of the washer. As the sand accumulates in the bottom of the washer, pieces of 2 by 4 inch lumber are inserted in the slots in the sides of the discharge gate and added from time to time so as to retain the sand but permit the wash water to flow away unhampered. The wash water and clay are disposed of in different ways. Some companies run the water into any natural drainage system possible. Others run the water to a settling basin where the clay is allowed to settle out and some of the water recovered or discharged to a convenient stream. From time to time the settling basin is cleaned out and the clay removed to some convenient place of disposal.

When one washer is full the sand from the screen is diverted to another washer and a valve in the bottom of the first washer is opened. The sand commonly passes by gravity to another washer where the process of laundering is repeated. In general the washers are operated in pairs so that when one set is filling up the other is emptying, thus insuring continuous performance and handling of material.

DRAINING THE SAND

From the second set of washers the sand is pumped into the draining bins (fig. 27). As it enters the bins it is further washed by a stream or spray of water directed upon it. Two general types of draining bins are employed, those with flat bottoms and those with inclined bottoms. The former consist of a square or rectangular concrete bin, with the bottom slightly sloping to permit the water draining from the sand to run off. The bins of one company are 30 feet square and 12 feet deep. Over the concrete floor of the bins is placed a layer of coarse cinders or gravel, and this in turn is overlaid by a bed of fine gravel or cinders. A floor of 2 by 4 lumber is laid over the cinders or gravel. The water from the sand trickles through the cracks in the wooden floor and through the cinders or gravel beneath and then runs out of a drain in the concrete floor.

Fig. 27. Draining bins of Ottawa Silica Company. The sand is pumped from the washers into the bins and may be seen spraying out from the pipe at the right. The overhead crane removes the sand from the bins to the driers beneath the ridge of sand along the left wall of the building. (Photograph by courtesy of Ottawa Silica Company.)

The draining bins with inclined bottoms are rectangular, square or round and are most commonly made of wood. The floor of the bin is inclined at an angle of about 45° and the water drains from the sand to a trough which conveys it away. The sand is usually allowed to drain for 24 hours or more according to the season and character of the weather.

Where flat-bottomed bins are used, the drained sand is commonly conveyed to the driers by overhead cranes (fig. 27). The inclined-bottom bins are usually arranged so that the sand discharges through doors in the side of the bin at its deepest part directly on to the driers (fig. 22).

DRYING THE SAND

Two general types of driers are in use, the steam coil drier and the cylindrical rotary drier. The former commonly consists of tiers of iron pipe which run back and forth across the length or width of the drier. The pipes are heated by steam. The drained sand is placed upon these pipes and as it dries it falls between them on to a conveyor belt which runs beneath the drier parallel to its longest dimension. One company has a drier 85 feet long.

The cylindrical drier consists of a rotating steel cylinder, slightly inclined towards its discharge end. One type of cylindrical drier has steam heated pipes on the inside, another has a flame directed into it. The wet sand is fed into the receiving end of the drier and is dried during its movement to the discharge end.

SCREENING THE SAND

The sand from the conveyor belt which passes beneath the drier is discharged into a bin from which it is commonly conveyed to the top of the screen house by a bucket belt elevator. The elevator discharges into a bin which distributes the sand to various screens. These are commonly of the vibrating type. Many are Hummer or Whip-tap screens and others of home manufacture. Commonly the screens are employed in batteries of two or three, the screens of each battery performing a similar part in the operation of screening. The various products from the screens pass by gravity down wooden spouts into the storage bins.

SHIPPING THE SAND

The box cars in which the sand is to be shipped are run alongside of the storage bins and the sand is spouted into them. The cars are commonly lined with paper before loading. Some glass companies have special types of box cars which they own and which are used exclusively for the transportation of glass sand.

THE MANUFACTURE OF SPECIAL SANDS OR SAND PRODUCTS

WASHED AND DRAINED SAND

Washed and drained sand is, as the name implies, sand which has been washed and drained but not dried. It is commonly run directly from the washers into hopper-bottom gondolas and allowed to drain on the track before shipment.

STANDARD OTTAWA SAND

This is a very carefully screened sand all of which passes a 20-mesh sieve and is retained on a 30-mesh. A special installation of shaker screens is used for sieving the sand. It is run over a magnetic separator which removes any pieces of steel that may have got into the sand from the steel brushes used in brushing the sieves and then is sacked for shipment.

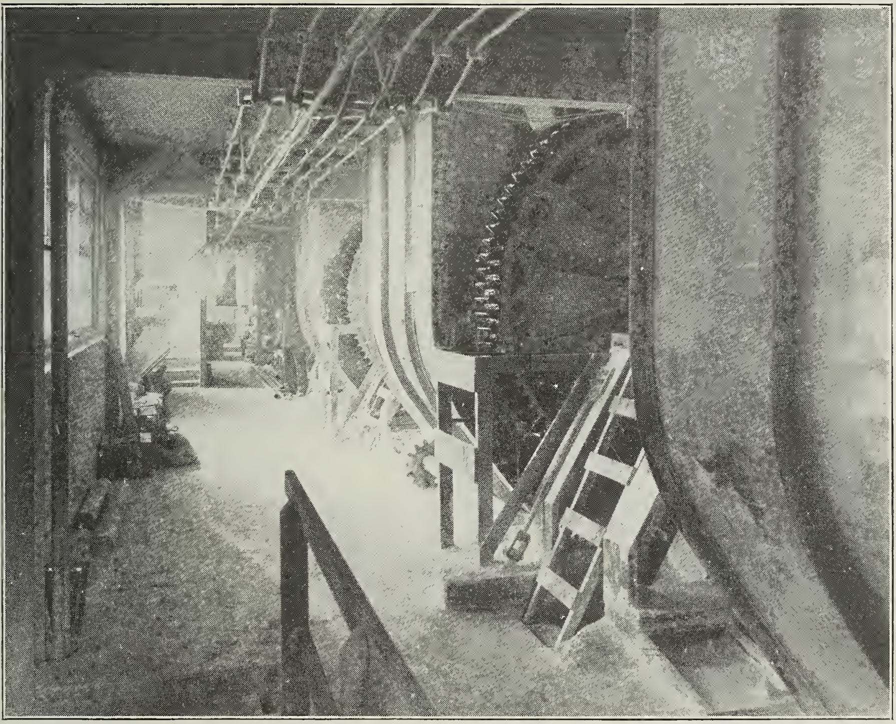


Fig. 28. Tube mills in plant of National Silica Company. Each mill is jacketed to catch the very fine silica dust produced during grinding. (Photograph by courtesy of National Silica Company.)

GROUND SAND OR SILICA

Ground silica is prepared by pulverizing washed and dried sand in tube mills (fig. 28). They vary in size. One plant has installed two mills, each 6 feet in diameter and 22 feet long. The tube mills are lined with Belgian flint blocks and Danish flint pebbles are used as grinders. The tube mills are slightly inclined and as they revolve the sand moves from the receiving end to the discharge end. From the tube mills the sand is elevated to bins which feed the sacking machines used for bagging the silica for shipment. Inasmuch as silica dust is injurious to the lungs, dust collectors are commonly installed about the dusty parts of the grinding operation or the workmen wear masks to prevent inhaling the silica dust. The finished product commonly will pass a 170-mesh sieve and be retained on a 200-mesh.

PRODUCERS OF WASHED SAND

The general procedure of quarrying, washing and manufacturing St. Peter sand has been described. The purpose here is to summarize the equipment at each plant and point out the salient departures in the production of sand which may be peculiar to any of the plants described, together with any miscellaneous items of interest concerning the various quarries or plants. The locations of the plants in the principal producing area, the Ottawa-Utica district, are shown in figure 29.

The plants will be described in the following order:

Ballou White Sand Company
Higby-Reynolds Silica Company
Ottawa Silica Company
Standard Silica Company
United States Silica Company
Wedron Silica Company
National Silica Company

Ballou White Sand Company

Location: west side of Fox River, in SE. cor. SW. ¼ NE. ¼ sec. 19, T. 36 N., R. 6 E., near Millington, Kendall County.

Quarry: pit quarry; 50-foot face.

Overburden: glacial gravel and boulders, overlain by 2 to 3 feet of black loam. Average thickness about 4 feet.

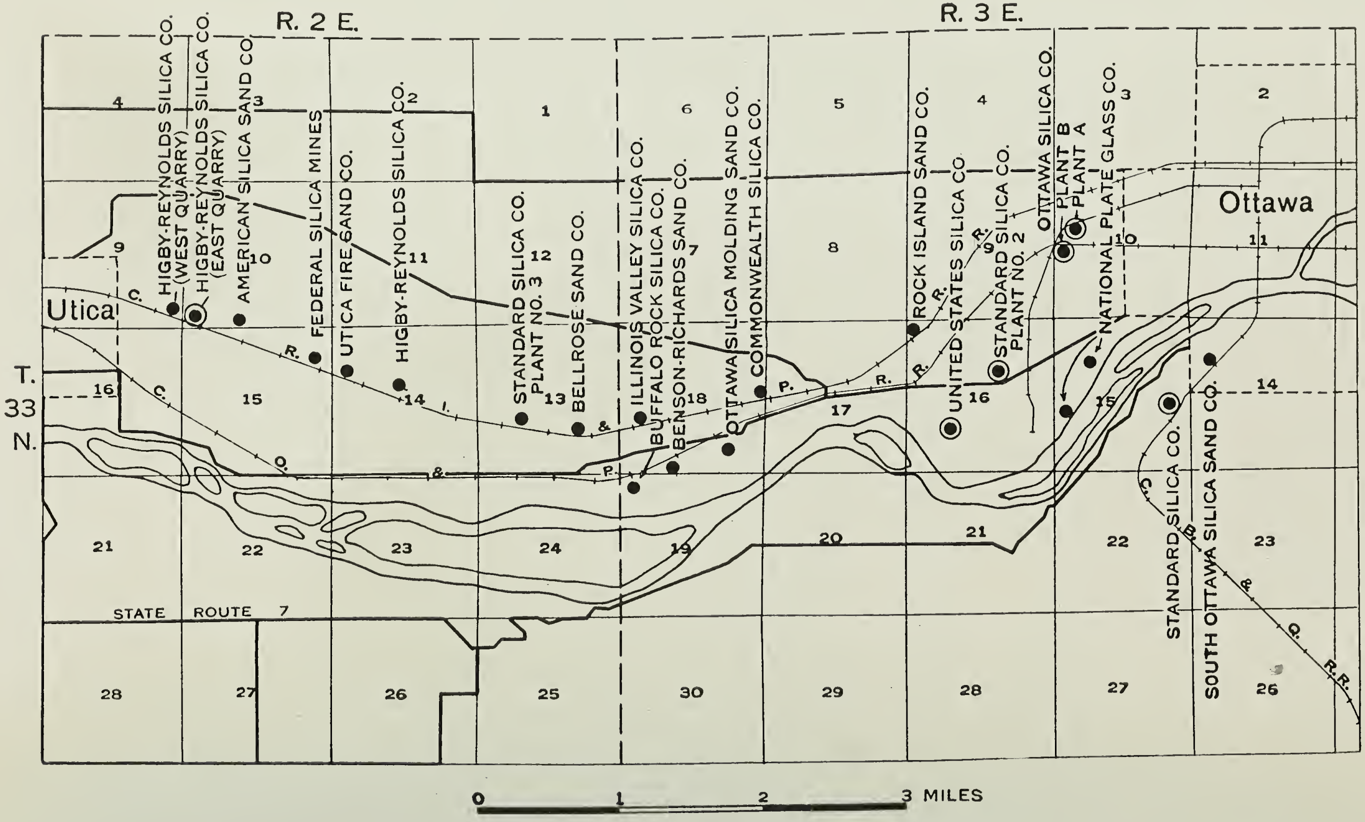
Equipment: cylindrical scalping screen, 2 washers, seven 10 by 20 foot inclined-bottom draining bins, 2 steam-coil driers; dried sand goes first over cylindrical Tyler screen about 14 mesh, then over stationary inclined screen. Steam power. Sand conveyed across Fox River to railroad by bucket cable tram.

Railroad: Chicago, Burlington and Quincy.

Water for quarrying and washing: quarry water. Wash water disposed of into Fox River.

Capacity: 200 tons per 10 hours.

Samples: No. 47 from the 37-foot northeast face; No. 50, plant run; Nos. 48 and 49 are from one of the lower beds in the quarry. The last two samples were taken about 300 feet from each other.



● Crude sand quarries. ◉ Washed sand quarries.

Fig. 29. Locations of the St. Peter sand quarries in the Ottawa-Utica district.

Higby-Reynolds Silica Company

(REYNOLDS EAST QUARRY)

Location: NW. cor. SW. ¼ SW. ¼ sec. 10, T. 33 N., R. 2 E., near Utica, La Salle County.

Quarry: slope quarry; 55-foot face.

Overburden: glacial drift and soil, averaging about 3 feet thick.

Equipment: flat scalping screen, 2 washers, three 15 by 15 foot draining bins with a 16-inch screw feed at bottom to conveyor belt, cylindrical revolving oil-fired drier, flat inclined screen, 52 inches by 30 feet. Steam power.

Railroad: Chicago, Rock Island and Pacific.

Water for quarrying and washing: artesian well.

Capacity: 200 tons per 9 hours.

Samples: No. 36 from quarry face; No. 37 is plant run.

Ottawa Silica Company

PLANT A

Location: SW. ¼ NW. ¼ sec. 10, T. 33 N., R. 3 E., northwest of Ottawa, La Salle County.

Quarry: pit quarry; 30-35-foot face.

Overburden: black loam, average thickness about one foot.

Equipment: 8 by 3 foot cylindrical scalping screen, 4 washers, four 30 by 30 by 12 foot flat-bottomed draining bins, sand taken from draining bins to drier by overhead clam-shell crane, steam-coil drier, Hummer and Whip-tap screens, electric power. Two tube mills, 6 by 22 feet, for grinding silica.

Railroad: joint switch to Chicago, Rock Island and Pacific, and Chicago, Burlington and Quincy, Illinois Traction.

Water for quarrying and washing: quarry water, well, and Illinois and Michigan Canal. Wash water run to settling tank and then to canal.

Capacity: 1400 tons per 24 hours.

Samples: No. 1 from west quarry face; No. 2 south quarry face; No. 3 east quarry face; Nos. 4 and 5 are from bed near bottom of quarry in east face and were taken about 400 feet apart; No. 6 is plant run.

PLANT B

Location: NW. cor. SW. ¼ sec. 10, T. 33 N., R. 3 E., near Ottawa, La Salle County.

Quarry: pit quarry; 30-35-foot face.

Overburden: black loam, average thickness about one foot.

Equipment: 8 by 3 foot cylindrical scalping screen, 4 washers, six 30 by 30 by 12 foot flat-bottomed draining bins, overhead clam-shell crane takes sand from draining bins to drier, steam-coil drier, Hummer and Whip-tap screens, electrically operated.

Railroad: joint switch to Chicago, Rock Island and Pacific, Chicago, Burlington and Quincy, and Illinois Traction.

Water for quarrying and washing: quarry water, well, and Illinois and Michigan Canal. Wash water to settling basin and then to canal.

Capacity: 2000 tons per 24 hours.

Samples: No. 7 from south face center workings; No. 8 is plant run.

Standard Silica Company

PLANT NO. 1

Location: NE. ¼ SE. ¼ sec. 15, T. 33 N., R. 3 E., southwest of Ottawa, La Salle County.

Quarry: pit quarry; 50-foot face.

Overburden: black loam, locally pebbly or clayey, average thickness about 3 feet.

Equipment: the primary washers have a taper at the end through which the wash water passes out. This is said to give the water greater velocity and to result in a cleaner sand. The secondary washers are the common rectangular type. There are 2 of each type of washers. Cylindrical silo draining bins, 10 by 19 feet with inclined bottom, steam-coil drier, "knocker" screens, electric and steam power.

Railroad: Chicago, Burlington and Quincy.

Water for quarrying and washing: quarry water, wash water run to settling basin and then to Illinois River.

Capacity: 1200 tons per day.

Samples: No. 43 from face, SW. corner of quarry; No. 44 is plant run.

PLANT NO. 2 (FORMERLY CRESCENT SILICA COMPANY)

Location: SW. ¼ NE. ¼ sec. 16, T. 33 N., R. 3 E., southwest of Ottawa, La Salle County.

Quarry: pit quarry; 75-foot face.

Overburden: black loam, average thickness about one foot.

Equipment: cylindrical scalping screen 2 by 5 feet, 4 washers, inclined bottom draining bins, 2 rotary steam-coil driers, vibrating screens, electrically operated.

Railroad: joint switch to Chicago, Rock Island and Pacific and Chicago, Burlington and Quincy.

Water for quarrying and washing: quarry water.

Capacity: 1200 tons per 24 hours.

Samples: No. 9 from quarry face; No. 10 is plant run.

United States Silica Company

Location: SW. ¼ sec. 16, T. 33 N., R. 3 E., southwest of Ottawa, La Salle County.

Quarry: pit quarry; face about 70 feet.

Overburden: black loam, average thickness about 2 feet.

Equipment: cylindrical scalping screen, 2 washers, 12 draining bins with inclined bottoms, steam-coil drier, Whip-tap screens, electrically operated.

Railroad: Joint switch to Chicago, Rock Island and Pacific and Chicago, Burlington and Quincy.

Water for quarrying and washing: quarry water, wash water to settling basin to Illinois River.

Capacity: 1200 tons per 24 hours.

Samples: No. 13 from north quarry face; No. 12 is plant run.

Wedron Silica Company

Location: center sec. 9, T. 34 N., R. 4 E., at Wedron, La Salle County.

Quarry: pit quarry, face 55 to 75 feet.

Overburden: glacial drift and soil, average thickness about 10 feet.

Equipment: rotary scalper, 4 washers, flat-bottom draining bins, overhead clam-shell crane from draining bins to drier, steam-coil driers, vibrating screens, electrically operated.

Railroad: Chicago, Burlington and Quincy.

Water for quarrying and washing: quarry water, wash water to settling basin to Fox River.

Capacity: 1000 tons per 24 hours.

Samples: No. 17, plant run; No. 18 face sample from south face of south workings; Nos. 19 and 20 bed samples from south face; No. 21 face sample from upper portion of exposure at one time quarried as molding sand.

National Silica Company

Location: NE. ¼ SW. ¼ sec. 8, T. 23 N., R. 10 E., west of Oregon, Ogle County.

This company's operations are unique in Illinois, inasmuch as the sandstone is not quarried hydraulically and is washed by a special apparatus; the product is used almost exclusively for one purpose, namely ground silica. The quarry and plant are therefore described in detail (fig. 30).

The sandstone quarried is more firmly consolidated here than in the Ottawa district and it is not feasible, therefore, to quarry it by hydraulic methods. Instead, regular rock quarrying methods are used (fig. 31). The quarry is a pit quarry and has a face averaging about 35 feet in height. The overburden is glacial drift and varies from 1 to 10 feet thick. The average is about 3 feet. The holes for the primary blasting are drilled with churn drills, the secondary blast holes with jack hammers. After the sand has been shot down it is loaded with a railroad type steam shovel, 1½ yard bucket, into 5-yard side dump cars. Dinkeys haul the cars to the plant. The cars dump on to an inclined bar grizzly with 3-inch openings. (See fig. 32.) The undersize falls into a hopper and the oversize goes into a roll crusher set at about 3 inches and then to the same hopper as the undersize. The hopper has a caterpillar tread feed to a conveyor belt which is about 250 feet in length from center to center. A movable trip at the upper end of the belt distributes the

Fig. 30. Plant of National Silica Company, Oregon, Illinois. On the left is the building housing the screening and pulverizing machinery, and just behind the tree in the center of the picture is the circular draining bin. The other buildings house the power plant and washing and drying equipment. (Photograph by courtesy of National Silica Company.)

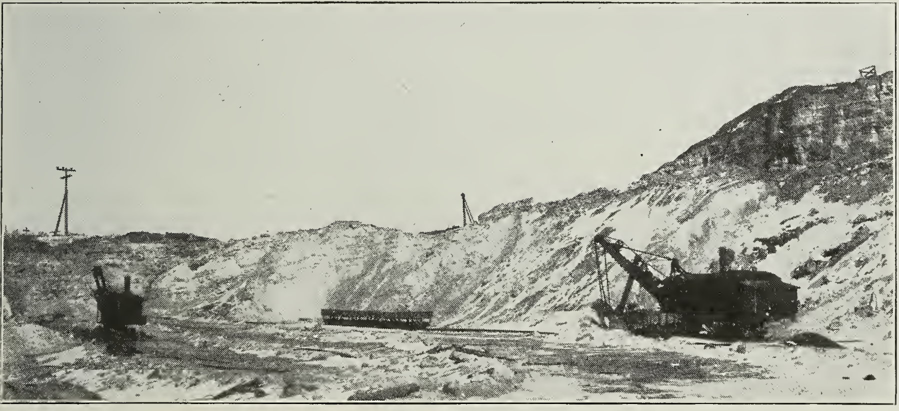


Fig. 31. Quarry of National Silica Company showing steam shovel used for loading sand, and cars which transport the sand to plant. (Photograph by courtesy of National Silica Company.)

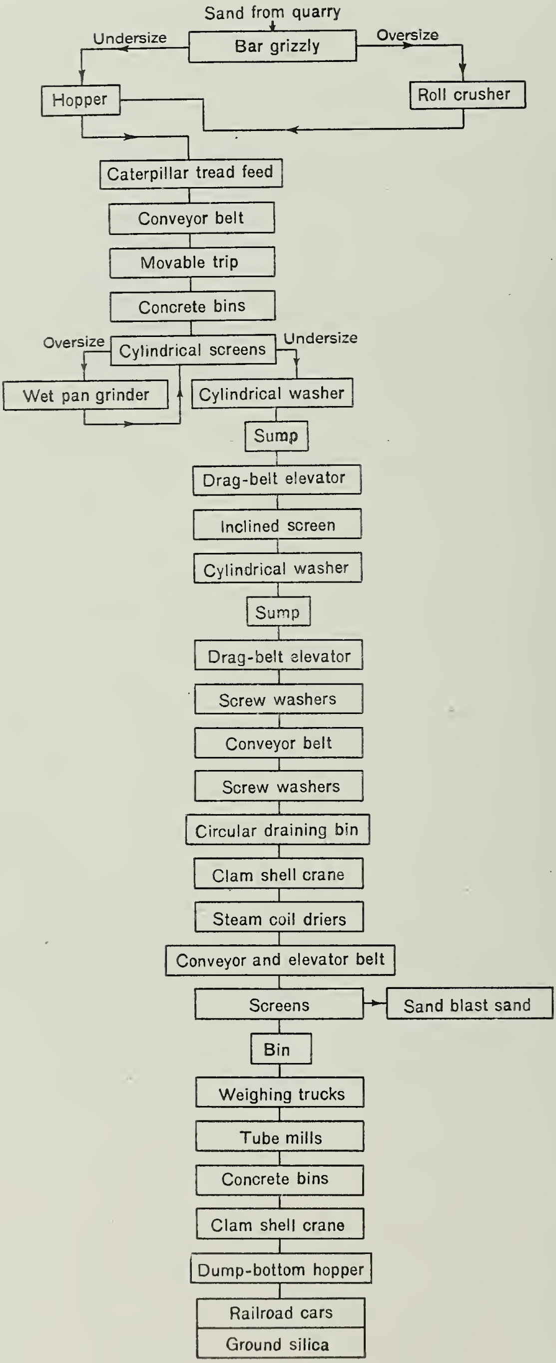


Fig. 32. Flow sheet of plant of National Silica Company.

sand to square concrete bins. From these bins the sand feeds by gravity into a 2 by 7 foot jacketed cylindrical screen. The screen has ½-inch openings; the jacket is about 10 mesh. The sand passing the screen goes to the washers. The oversize from the screens goes to a wet pan grinder. The sides of the pan are steel grating with ¼-inch vertical slits. The sand passes out through these openings and is conveyed back to the cylindrical screen. The sand passing the screen goes to two cylindrical concrete washers (fig. 33). There are three of these screening and grinding units. The washers are full of water when the sand from the screens come in and the addition of the sand and water from the pans and screens causes the washer to overflow; with the overflow the clay is carried off. When the first washer is full of sand a valve is opened and the sand is allowed to run out into a sump from which a drag-belt elevator conveys it to the top of a flume which discharges over an inclined screen into the second washer (fig. 33). About the upper two-thirds of the screen is 10 mesh and the lower third 14 mesh. From this second washer the sand again goes to a sump and is elevated by a drag belt to a battery of 5

Fig. 33. Circular washers in plant of National Silica Company. Note the flume discharging into the second washer. (Photograph by courtesy of National Silica Company.)

screw washers. After passing through these washers the sand is conveyed on a belt to a circular building housing another set of 5 screw washers. (See fig. 30). These are on an arm pivoted at the center of the building. The arm can be moved so that the washers discharge into any part of the circular draining bin which constitutes the lower portion of the building. The sand is removed from the draining bins by a clam-shell crane also attached to a movable arm pivoted at the center of the building and dried on steam-coil driers. A conveyor belt and an elevator belt carry the sand to the Hummer screens. During the screening process all material over 16 mesh is discarded. Some sand-blast sand is produced but a great part of the sand goes from the screens to a bin which feeds by gravity to weighing trucks. The operators of these trucks weigh out the charges for tube mills of which there are two 7 by 22 feet, six 6 by 11 feet and one 6 by 22 feet. (See fig. 28). On the average about 6 hours are required to grind one charge of sand. The tube mills are lined with Belgian flint bricks and French flint pebbles are used as grinders. The plant is equipped throughout with dust collectors. The capacity of the mills is about 160 tons of ground silica per 24 hours. From the mills the ground silica passes into concrete bins from which it is loaded by an overhead clam-shell crane into a dump-bottom hopper which feeds by gravity into railroad cars. The plant is operated by electricity throughout. Water for washing the sand is secured from two wells about 180 feet deep. After use it is run into a settling pond and reclaimed. The pond is cleaned out periodically with a drag-line bucket.

Sample 51 is from the 35-foot face on the east side of the quarry. No. 53 is plant run.

Sample 52 is from the sandstone exposed in the bluff along the north side of the railroad north of the quarry. The beds have an east dip of about 15°. The total thickness exposed and sampled is about 93 feet. Part of the 93 feet is probably the same strata as those from which sample 51 was obtained.

Crude Sand

GENERAL STATEMENT

The crude sand quarries, or molding sand quarries as they are sometimes called, are for the most part bluff quarries in contrast to the washed sand quarries which are mostly pit quarries. The crude sand workings are with three exceptions in the bluff along Illinois River between Ottawa and Utica. (See fig. 29, p. 77). In general the sand is yellow and contains more clay than that of the washed sand quarries. As a rule the crude sand quarries have a comparatively thick overburden whose removal is an important economic factor and item in the production of the sand.

In quarrying the sand it is the common practice to drill blast holes to about the level of the quarry floor along the upper edge of the quarry face with churn or tripod drills. When shot, holes drilled in this fashion bring down a large part of the face at one time. Another method, gopher-holing, consists of drilling horizontal holes into the face with water-jet drills. These are sprung with a light shot and then cleaned out and re-loaded with a heavier charge which when exploded also brings down a large quantity of sand.

Many different methods are in use for getting the sand from the quarry face to the railroad cars. They depend upon the location of the quarry face with reference to transportation, to some extent on the physical character and topography of the deposit, and upon the grades which it is desired to produce. A brief mention will therefore be made of the method of quarrying under the description of each of the quarries.

Fig. 34. Churn drill used for making primary blast holes. (Photograph by courtesy of American Silica Sand Company.)

PRODUCERS OF CRUDE SILICA SAND

The following is a list of the producers of crude silica sand in Illinois. The operations of the different companies will be described in order.

American Silica Sand Company
Bellrose Sand Company
Benson-Richards Sand Company
Buffalo Rock Silica Company
Commonwealth Silica Company
Federal Silica Mines

Higby-Reynolds Silica Company
Illinois Valley Silica Company
National Plate Glass Company
Ottawa Silica Molding Sand Company
Rock Island Silica Sand Company
South Ottawa Silica Sand Company
Standard Silica Company
Utica Fire Sand Company
Wilkinson Sand Company

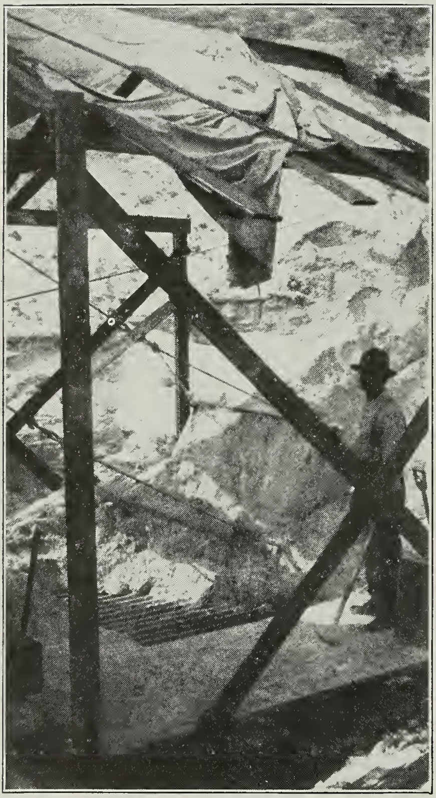


Fig. 35. Drag-line scraper bringing sand on to bar grizzly. (Photograph by courtesy of American Silica Sand Company.)

American Silica Sand Company

Center S. ½ SE. ¼ SW. ¼ sec. 10, T. 33 N., R. 2 E., near Utica.

This quarry is located in the north bluff of Illinois River. The overburden consists of about equal amounts of glacial drift and soil, and is removed by means of teams and scrapers. A face 60 feet high is being worked in two benches. The holes for the primary blasting are drilled 30 feet deep with a churn drill (fig. 34). The disintegrated sandstone is conveyed by a closed-bottom, drag-line scraper to a grate with two-inch openings (fig. 35) and falls directly into railroad cars beneath the grate. Steam power is used. The capacity of the equipment is 600 tons per 8 hours.

The upper 30 feet of sandstone is sold for molding sand. Sample 40 comes from this upper 30 feet of sandstone from the east face. Sample 41 comes from the lower 30 feet on the southeast side of the quarry. The sand from the lower 30 feet is sold as fire and furnace sand.

No. 2 quarry of this company about a half mile east of Utica in the north bluff of Illinois River was not in operation (fig. 36).

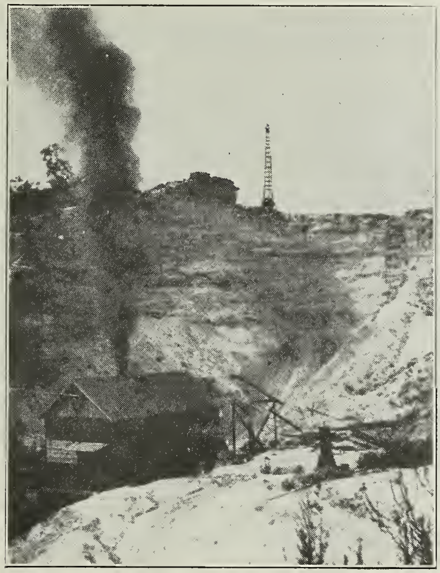


Fig. 36. The No. 2 quarry of the American Silica Sand Company. (Photograph by courtesy of American Silica Sand Company.)

Bellrose Sand Company

SW. cor. NE. ¼ SE. ¼ sec. 13, T. 33 N., R. 2 E., between Ottawa and Utica.

The quarry is located in the north bluff of Illinois River. The overburden averages about 10 feet in thickness and consists of clay, coal, glacial drift and soil. It is removed by a drag-line scraper operating from a dead man and is overcast back from the working face. During the winter months when most of the stripping is done, a steam shovel is also employed for the same purpose. A face of about 60 feet is being worked. The blasted sand is loaded with a steam shovel, one-yard bucket, into a movable hopper set on a track above the primary conveyor belt. The hopper and conveyor are movable laterally along the working face. The primary conveyor belt elevates the sand to the screening and crushing plant, and discharges to a grizzly. The sand passing the grizzly goes through two roll crushers set at 5 and 3 inches and then to a cylindrical screen with ¾-inch perforations. The fines fall directly on to a conveyor belt which discharges to the railroad cars. The oversize goes to another roll crusher set at one inch which discharges into a second screen with ½-inch perforations. The fines from this screen discharge on to the conveyor which loads to the railroad cars and the oversize goes to another set of rolls set at ¼ inch, and thence to the loading conveyor.

The capacity is about 1200 tons per 8 hours.

Sample 25 was obtained rom the west end of the quarry face. It does not include the upper 8 feet of sand which was inaccessible.

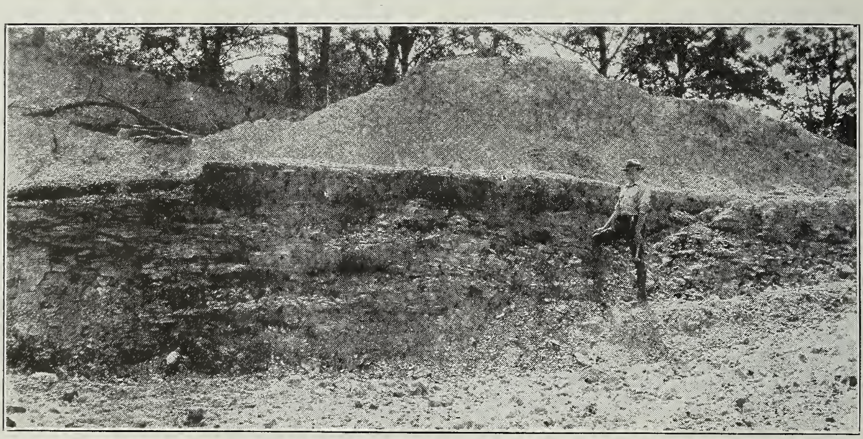


Fig. 37. The overburden at the quarry of the Benson-Richards Sand Company. The floor of the exposure is the top of the St. Peter sandstone. This is overlain by about 6 feet of clay containing many St. Peter sand grains. Above the clay and beginning at about the level of the man's waist is a bed of coal about 18 inches thick. The material above the coal is glacial clay.

Benson-Richards Sand Company

Center S. ½ SE. ¼ SW. ¼ sec. 18. T. 33 N., R. 3 E., near Ottawa.

This quarry is located in the north side of Buffalo Rock, an isolated rock hill in the flood-plain of Illinois River. The overburden has been overcast a number of times so that the thickness of the normal overburden is only roughly determinable. The following succession of strata was uncovered during recent stripping: (See fig. 37.)

	Thickness *Feet*
5. Glacial drift	?
4. Shale, gray, nodular, plastic	3 to 8
3. Coal, badly weathered, friable, no pyrite	1 to 2
2. Clay, gray, with numerous St. Peter sand grains	3 to 6
1. Sandstone (St. Peter)	

The removal of the overburden is accomplished chiefly by a drag-line scraper operating from a dead man. The coal uncovered during the operations is saved for steam purposes.

A face of 50 feet of sand is being worked. The holes for blasting are drilled with air drills and average about 13 feet in depth. The sand is conveyed by a V-shaped scraper to a grizzly with five-inch openings. The oversize consists principally of spalls which are discarded. The sand passing the grizzly falls to a gasoline-driven portable belt loader which discharges over a ½-inch screen into the railroad cars. The capacity is about 300 tons per 8 hours at one loading point.

Sample 14 was taken from the face at the west end of the quarry, sample 15 from the bottom 5 feet of sand in the west end of the quarry, and sample 16 from the same bed at the east end.

Buffalo Rock Silica Company

NW. ¼ NW. ¼ sec. 19, T. 33 N., R. 3 E., in Buffalo Rock.

The quarry is located in the southwest corner of the west end of Buffalo Rock. A face 70 feet high is being worked. Roughly the upper 30 feet of sand is colored deep yellow by iron oxide, but below this depth the amount of iron oxide decreases progressively. The thickness of the overburden varies from almost nothing to 15 feet, and averages about 9 feet. A section of the overburden at the east end of the quarry is as follows:

	Thickness	
	Ft.	*In.*
Soil	7	
Clay	3	
Coal		18 to 30
Clay	2	
St. Peter sandstone		

Stripping is carried on by a Marion type 7 steam shovel.

The sand is loaded by a clam-shell crane with a 50-foot boom and a 1½-yard bucket to a hopper at the top of the crushing and loading unit (fig. 38). This unit is unique in that it is on the same rails as the crane and is moved back and forth parallel to the quarry face by the crane. The mobility of this loading unit makes the shifting of railroad cars unnecessary during loading operations. From the hopper the sand passes through a primary crusher on to a ¾-inch vibrating screen. The fines from this screen fall on the conveyor belt which discharges to the railroad cars. The oversize from the screen goes to a set of rolls and then to the discharge belt. The capacity of the plant is about 60 cars in 12 hours. The sand is shipped on the Illinois Traction System.

Sample 45b was taken from the face of this quarry.

Commonwealth Silica Company

Center E. line sec. 18, T. 33 N., R. 3 E., near Ottawa.

The quarry is located in the north bluff of Illinois River. The face is about 50 feet high with an overburden of Pennsylvanian sediments, glacial drift and loess which varies from a thickness which is almost negligible to one of 25 feet. A large portion of the sandstone is colored deep yellow by iron oxide, and is worked selectively by pick, shovel and wheel barrow. Continuous operation is not maintained and sand is loaded only to fill special orders. Near this quarry are entries of abandoned mines which were the source of St. Peter in the past.

Sample 45a was taken from the face of the quarry.

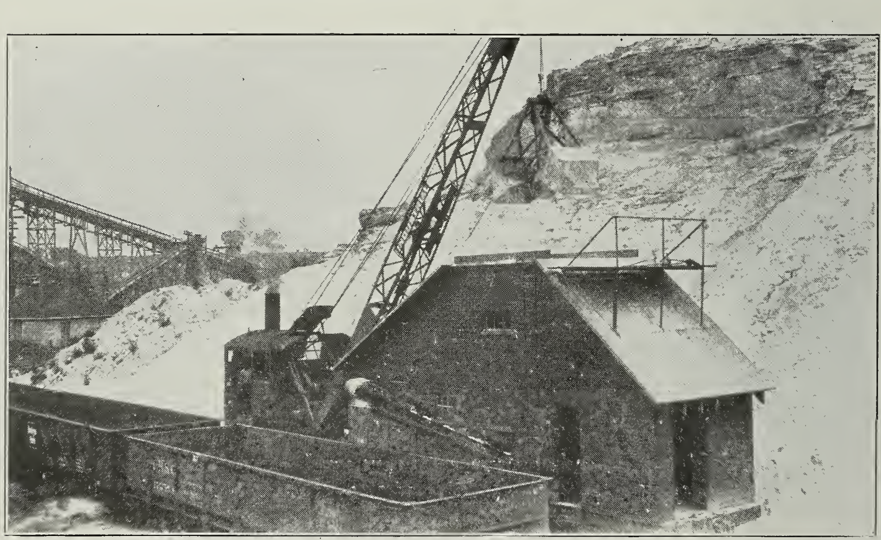


Fig. 38. The quarry, and loading, crushing, and screening machinery of the Buffalo Rock Silica Company. (Photograph, courtesy of Pit and Quarry.)

Federal Silica Mines

Center S. ½ NE. ¼ NE. ¼ sec. 15, T. 33 N., R. 2 E., near Utica.

The quarry is located in the north bluff of Illinois River about two miles east of Utica. The overburden averages about 18 feet in thickness of which the lower 16 feet is glacial drift and the upper 2 feet soil. The overburden is removed by a steam shovel, ¾-yard bucket, loaded into two-yard side dump cars, hauled by a gasoline dinkey and disposed of into an adjoining ravine.

A face of about 60 feet is being worked in benches of 30 feet. Blasting is carried on by drilling horizontal holes to a depth of 20 feet. The sand is conveyed from the face by a closed-bottom drag-line scraper, steam operated, to a grizzly with two-inch openings, through which it falls into railroad cars. The capacity is about 450 tons per 8-hour day.

Sample 34 comes from the upper 30 feet of sand which is sold as steel molding sand, and sample 35 from the lower 30 feet of sand which is sold as furnace bottom and fire sand.

Higby-Reynolds Silica Company

(HIGBY CANYON QUARRY)

NE. cor. SE. ¼ NW. ¼ sec. 14, T. 33 N., R. 2 E., near Utica.

This quarry is located on the west side of Higby-Ravine a short distance up the ravine from the bluffs of Illinois River. The overburden averages about 6 feet in thickness. Locally it is glacial drift and soil; in other places it is clay, coal and shale. It is removed by loading with a steam shovel, 1¾-yard bucket, to 4-yard side dump cars which are pulled by a dinkey to an adjoining ravine, and dumped. Any coal included in the overburden is recovered during the stripping operations.

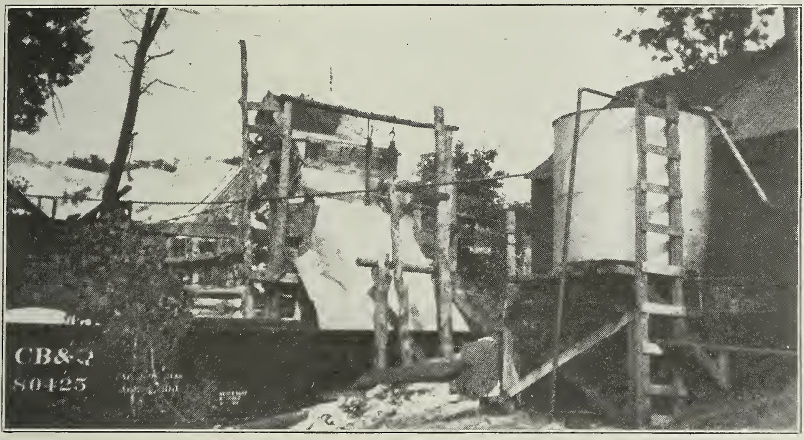


Fig. 39. End dump car discharging into railroad car. (Photograph by courtesy of American Silica Sand Company.)

Two levels of 25 feet each are being worked. On the upper level a steam shovel with a ⅞-yard bucket loads the sand into 4-ton side dump cars which are pulled by a dinkey to a chute into which the cars are dumped. The chute discharges into railroad cars. On the lower level a V-shaped or "arrow" open-bottom scraper and drag line convey the sand to a grizzly through which the sand discharges into 11-ton end dump cars. These are pulled by cable and dumped by a trip into railroad cars (fig. 39). The output capacity from both levels is about 1800 tons per 8 hours.

The sand from the upper level is sold as steel molding sand. Sample 28 comes from the north face of the upper level; sample 29 comes from the east face of the upper level; sample 32 is from the lower level. Most of the sand produced from the lower level is sold for core sand. Certain portions of the lower sand are sold as welding sand and magnesia sand. Sample 30 comes from a 5-foot bed of welding sand and sample 31 from an 8-foot bed of magnesia sand.

Higby-Reynolds Silica Company

(REYNOLDS WEST QUARRY)

NE. ¼ SE. ¼ SE. ¼ sec. 9, T. 33 N., R. 2 E., near Utica.

This quarry is located in the north bluff of Illinois River and is west of the washed sand quarry owned and operated by the same company. The overburden averages about 2 feet in thickness and consists of glacial drift and soil. It is removed by teams and scrapers to a dump heap.

A face about 100 feet high is being worked in two benches of 65 and 35 feet. The upper, or 65-foot face, is worked by drilling 65-foot holes with a churn drill and the entire face is shot down at once. The lower face was not being worked when the quarry was visited. Drilling of secondary blast holes in large sandstone blocks is done with a steam jackhammer. Two distinct quarrying units are in operation, each consisting of a closed-bottom drag-line scraper operated by a steam engine, which conveys the sand from the face to a grizzly with 3-inch openings. The sand falls through the grizzly to 11-ton end dump cars which are pulled by a dinkey to the railroad spur where they dump into the railroad cars. The capacity is about 1100 tons per 9 hours.

Sample 38 is from the east face of the upper or 65-foot ledge. Sample 39 is from the lower 35 feet of sandstone. When the market warrants, the lower face is worked for furnace bottom sand.

Illinois Valley Silica Company

NW. ¼ SW. ¼ sec. 18, T. 33 N., R. 3 E., near Ottawa.

The quarry is located in the north bluff of Illinois River. The overburden averages about 10 feet in thickness and where thick is made up as follows:

	Thickness *Ft.*	 *In.*
5. Glacial drift and soil	1 to 3	
4. Shale	14±	
3. Coal	1	10
2. Fire clay, sandy	1 to 3	
1. St. Peter sandstone		

The overburden is removed by a full revolving drag line with a long boom and a drag-line bucket. It is loaded into dump cars and disposed of in a nearby ravine.

The height of the quarry face varies from 50 to 65 feet and averages about 60 feet. Blast holes are drilled with a well drill to a depth of 60 to 65 feet and the entire face shot at one operation. The blast holes are spaced 15 feet apart and 15 feet from the face. A V-shaped open-bottom drag-line scraper conveys the sand to a rail grizzly with 6-inch openings. The sand is reduced by sledging until it passes the grizzly. It falls through the grizzly to a conveyor belt which takes it to a cylindrical screen with ½-inch square mesh. The fines from this screen fall to a conveyor belt which carries them to the railroad cars. The oversize goes to a jaw crusher set at 2 inches and then to a set of rolls set for ½ inch. The sand coming from the rolls falls on to the same conveyor which takes the fines from the cylindrical screen to the railroad cars. The capacity is about 1000 tons per 9 hours.

Sample 26 is a grab sample taken from ten loaded railroad cars. The character of the quarry face made other sampling impossible.

National Plate Glass Company

SW. ¼ NW. ¼ sec. 15, T. 33 N., R. 3 E., near Ottawa.

This quarry is about 1200 feet long and 65 feet wide and is located on the northwest side of and close to Illinois River. The overburden is 3 to 8 feet thick and consists largely of black and brown soil with a little glacial gravel and clay just above the sandstone. It is overcast into piles, and then is loaded by a steam shovel and locomotive cranes into railroad cars in which it is conveyed to waste piles.

The quarry is being deepened in 12-foot benches. The present face of the quarry is about 30 feet. The blast holes are drilled 8 feet apart on a square pattern. During blasting the sand is so broken up that it requires no further treatment. It is loaded to railroad gondolas by a steam locomotive clam-shell crane with a 65-foot boom. The crane moves back and forth on tracks which parallel the length of the quarry.

The entire output of the quarry is used by the National Plate Glass Company at their plant a short distance away for grinding and polishing glass. Sample 24 was taken from the east end of the present quarry. Sample 23 was taken from the north end of another older quarry a few hundred feet west of the present quarry which is also a source of grinding and polishing sand. The old quarry has a 40-foot face. It was not in operation when visited.

Ottawa Silica Molding Sand Company

Center SE. ¼ sec. 18, T. 33 N., R. 3 E., near Ottawa.

This quarry is located in the north face of the isolated rock hill known as Buffalo Rock. The overburden varies greatly in thickness. It has been overcast a number of times and consequently the thickness is hard to determine. During stripping operations the following section was revealed:

		Thickness *Feet*
5.	Soil and glacial drift	2
4.	Shale, plastic, gray, nodular. Upper beds which are covered by soil and drift probably contain sandstone lentils	18±
3.	Coal, woody, locally charcoal	2 to 3
2.	Clay, gray, amorphous, containing many St. Peter grains	2 to 7
1.	St. Peter sandstone	

A steam shovel and gasoline shovel are used to load the overburden which is dumped in an adjoining valley.

The quarry has about a 60-foot face. The holes for blasting are drilled with air drills to the entire depth of the face. The broken sandstone is loaded by a revolving electric shovel with a 1 1/3-yard bucket (fig. 40) to a grizzly with 6-inch openings over a large hopper. The sand falls from the hopper to a conveyor belt which carries it to the crushing plant located a short distance away from the quarry. The belt takes the sand to a 4 by 16-foot revolving screen with ½-inch perforations. The sand passing this screen goes by a conveyor belt to the railroad cars. The oversize from the revolving screen goes to a hammer mill and through it to a conveyor belt which takes the sand to a vibrating screen with ½-inch openings. The undersize goes by conveyor to cars. The oversize is removed by wheel barrow and discarded. The capacity of the plant is about 1500 tons per 9 hours.

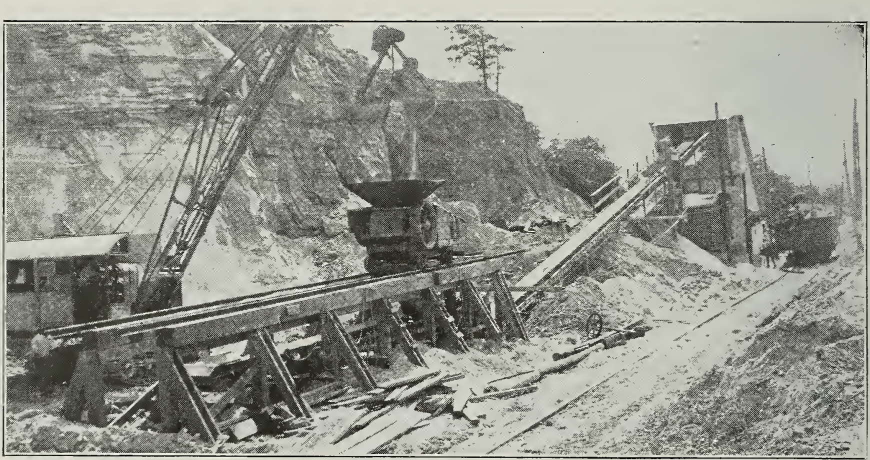


Fig. 40. The quarry and plant of the Ottawa Silica Molding Sand Company.

Sample 11 is taken from the face of sand exposed in this quarry.

Rock Island Silica Sand Company

NW. cor. sec. 16, T. 33 N., R. 3 E., near Ottawa.

This quarry is located a short distance northeast of Twin Bluffs in the north wall of Illinois Valley. The overburden is heavy and the operations not extensive.

The quarry was not in operation when it was visited but the sand is apparently loaded by hand into wheelbarrows in which it is wheeled to the railroad cars.

Sample 42 is from the 25 feet of sandstone exposed at this quarry.

South Ottawa Silica Sand Company

Center S. ½ NW. ¼ NW. ¼ sec. 14, T. 33 N., R. 3 E., near Ottawa.

This quarry is located in the flat of Illinois River just north of the bluff on the south side of the stream. The overburden averages about 2 feet in thickness and consists of brown and black loam. It is overcast away from the quarry face into piles by a full revolving steam crane with a 50-foot boom and 2-yard bucket.

The quarry is rectangular, long and narrow, and has a 30-foot face. It is being lengthened to the west. The blast holes are drilled horizontally and the broken sandstone loaded into a hopper by the same steam crane used at times for moving overburden. The crane is situated on the upper edge of the quarry face. From the hopper the sand feeds into a cylindrical rotary grizzly made of steel rails set ⅞ inch apart. The sand falls through the grizzly on to a conveyor belt which deposits it in the railroad cars. The grizzly and belt are operated by electricity. The capacity is about 1200 tons per 8 hours.

Sample 45 is from the west face of the quarry.

Standard Silica Company

(PLANT NO. 3)

Center NE. ¼ SW. ¼ sec. 13, T. 33 N., R. 2 E., between Ottawa and Utica.

This quarry is owned by the same company operating the washed sand plants in the Ottawa district. It is located in the north bluff of Illinois River. The overburden averages about 6 feet in thickness and consists of the following:

	Thickness	
	Ft.	*In.*
5. Soil and glacial drift	1 to 2	
4. Shale	2 to 3	
3. Coal	1	10
2. Clay, sandy	1 to 2	
1. St. Peter sandstone		

The overburden is removed by steam shovel and dump auto trucks.

A face about 55 feet high is being worked. It is shot by gopher holing. Holes are drilled about 20 feet into the base of the face, sprung with a light shot, cleaned out and reloaded with a heavy charge. Two or three holes are usually shot at one time. The sand is conveyed from the face by a drag-line scraper to a grizzly with 4-inch openings, through which it passes to a revolving screen. The oversize from this screen is discarded and the sand passing falls to a pile from which it is loaded by a drag-line scraper to 12-ton end dump cars. These are pulled by cable to a platform with a trip and discharged to the railroad cars. Steam power is used for the quarrying operations. The capacity of the quarry is about 1000 tons per 9 hours.

Sample 27 was taken from the face at center of the quarry.

Utica Fire Sand Company

SW. cor. NW. ¼ NW. ¼ sec. 14, T. 33 N., R. 2 E., near Utica.

This quarry consists of two individual workings which are essentially the same. The overburden on the sandstone averages about 8 feet in thickness and is removed by teams and scrapers. It consists of about 6 feet of glacial drift and 2 feet of soil.

A face about 70 feet in height is being worked. The sand is moved by closed-bottom scrapers to a grizzly with 5-inch openings which discharge into the railroad cars. The scraper is operated by a steam engine. The capacity production is about 800 tons per 9 hours.

The sand is sold principally for steel molding. Certain beds of sand, however, are quarried for magnesia and core sand when demand warrants such a procedure.

Sample 33 was taken from the northwest face of the westernmost of the two workings. The upper 8 feet of sandstone was inaccessible and is not represented in the sample.

Wilkinson Sand Company

NE. cor. SW. ¼ NW. ¼ sec. 16, T. 34 N., R. 4 E., near Wedron.

The quarry is located at the intersection of a small valley and the west bluff of Fox River. A 30- to 70-foot face is being worked. The upper 15 feet of sandstone is brown and streaked with yellow and the lower 15 feet buff or white. The overburden averages about 4 feet in thickness and consists of soil and a little gravel. The holes for blasting are drilled 28 feet deep with water-jet drills, and the sand is loaded by a ¾-yard steam shovel to 4-yard side dump cars which are pulled to a tressel by a dinkey and dumped directly into railroad cars. The capacity of the operation is about 20 cars per 12 hours. The sand is shipped on the Chicago, Burlington and Quincy Railroad.

Sample 45c is from the face of this quarry.

Grades of Washed and Crude Sand Produced

WASHED SAND

No strictly standardized grades of washed sand are produced. However, the different grades sold group themselves in a general way as follows:

MINE-RUN SAND

Mine-run sand, sometimes called quarry- or plant-run sand, is, as the name implies, the sand as it is delivered from the drier without preparation further than washing and drying. The size of the sand varies somewhat according to the particular quarry and the portion of that quarry from which it comes. This type of sand is used commercially when the size of the grains is not important.

WASHED AND DRAINED SAND

This type of sand is the same as mine-run except that it is not dried. It is commonly run from the washers directly to railroad cars and allowed to drain on the track. It is used chiefly for steel molding when a sand free from natural bond is desired.

SAND-BLAST SAND

Sand-blast sand is in general the coarsest of the manufactured grades of sand. Specifications of the manufacturer vary somewhat but in general from 95 to 100 per cent is retained on a 40-mesh sieve and 100 per cent or less passes the 20-mesh sieve. As the name suggests the sand is sold principally for sand blasting, and also for grinding and polishing, filter and roofing sand.

GLASS SAND

This is a very variable grade of sand. Following are the data on the size of the sand sold for glass given by the various producers: 65 per cent through 40 mesh, 85 per cent retained on 60 mesh; quarry run; through 35 mesh and retained on 65 mesh; 80 per cent retained on 60 mesh; all through 30 mesh; 70 per cent through 40 mesh, all retained on 70 mesh. This grade of sand has many uses outstanding among which are for making plate glass, as engine sand, and in the manufacture of carborundum, stucco, and sodium silicate.

BANDING SAND

Banding sand is a relatively fine grade of sand. It commonly all passes 50 mesh and is largely retained on about 120 mesh. It is used principally for frosting and polishing glass, for certain types of sand blasting where a fine sand is desired, for surfacing fireproof roofing and in making soaps.

MISCELLANEOUS

Some producers make grades known as extra fine, double extra fine, or other like names. These grades are commonly sand through 60 or 80 mesh.

GROUND SILICA

Ground silica prepared by grinding sand commonly varies between 90 and 300 mesh according to the use for which it is intended. Some companies which have dust collectors around their tube mills sell the accumulated silica dust as air-floated silica. It is a fine grade of ground silica. Ground silica is sold as a mold wash, and for making glazes, metal polishes, abrasive soaps, composition flooring, paint fillers and the like.

CRUDE SAND

No accurately delineated grades of crude sand are produced. According to the purposes to which the user finds the sand best suited, the quarry product is sold as steel molding sand, core sand, fire sand, furnace bottom sand, and welding sand. No attempt is generally made, however, to produce a sand of a standard sieve analysis. All the above grades of sand are generally sold without further preparation than reduction to pass a grizzly or screen with openings which may vary from ½-inch to 3 inches. Any further crushing or screening of the sand is done at the foundry or plant where the sand is used. The variations in the physical constitution of the crude sand sold for molding and the like are illustrated by the analyses given in the table of fineness tests (pp. 148, 150).

CHAPTER V—THE USES OF SAND AND OF THE ST. PETER SAND

This chapter is intended as a compendium of the uses of sand with particular reference to the St. Peter sand. In describing the uses of sand the plan followed includes a brief statement of the use the particular sand serves, the specifications, if any, for the sand, and a brief discussion of the properties of the St. Peter sand which makes it particularly suited to the use mentioned. The uses of sand are listed below in the order of discussion.

GROUND SAND AS AN ABRASIVE

Ground sand is used as an abrasive in metal polishes, soaps, and scouring pastes, for polishing bone and pearl buttons, and as a cleaning and polishing agent in tooth pastes and by dentists.

SAND AS AN ABSORBENT

Before the time of blotting paper, sand was sprinkled over wet writing to absorb surplus ink. It is used at the present time to a limited extent as an absorbent for strong chemical liquors. A sand composed of fine, rounded grains is preferred for this purpose.

AGRICULTURAL SANDS

Sand is sometimes added to heavy soils to improve their texture. It increases the openness of the soils which results in freer drainage. Agricultural testing sand is used by laboratories for making tests on soils. The sand used for this purpose is a well-graded, high silica sand.

SAND FOR ANNEALING[1]

To cool hot articles very slowly, they are sometimes covered with fine sand, called annealing sand, which prevents the rapid escape of heat. In general any fine sand is satisfactory for annealing purposes.

GROUND SAND FOR ASBESTOS SHINGLES[2]

As much as 40 per cent of silica, ground to pass 200 mesh, is sometimes used in the manufacture of asbestos shingles. It is essential that the silica be colorless.

SAND FOR ASPHALT PAVEMENTS

Asphalt cement, prepared by mixing refined asphalt with a flux and heating it, is used for making three different types of pavements, each of which may involve the use of sand. The three types of pavements are: sheet asphalt, asphaltic concrete, and asphalt block pavements. Their construction and the requirements for the sand for each will be discussed in order.

SHEET ASPHALT PAVEMENTS

A sheet asphalt pavement consists primarily of a concrete foundation, a binder course of asphalt cement and stone, and a wearing course of asphalt cement and sand. The sand used in the concrete should presumably meet the

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[1] Searle, A. B., Sands and crushed rocks, vol. 2, p. 228, London, 1923.
[2] Cole, L. H., Silica in Canada, Part I: Canada Dept. Mines, Mines Branch No. 555, p. 33, 1923.

requirements specified for concrete on page 110. The binder course is of two kinds, the open and the closed. In the former the use of sand is uncommon or merely incidental; in the latter, however, the sand is added to fill the voids between the pieces of stone. One large city uses sufficient sand to make up about 25 per cent of the total batch of the binder.[3] No specifications are reported for sand for use in the closed binder course.

The wearing or upper course of a sheet asphalt pavement is commonly composed of about three-fourths sand and one-fourth asphalt cement and filler which may be either Portland cement or rock dust. The character of the sand is an important item in this portion of the pavement.

The sand should be hard, durable, and free from organic material and easily broken rock fragments such as shale, coal and slate. It should not contain clay or loam except in very small amounts. Regarding the shape of the grains of the sand to be used Agg says: "It is generally thought that the sharp sand is better than sand made up of rounded particles, but this cannot

TABLE 5.—*Standard gradings for sand for sheet asphalt pavements*

Grade of sand	Passing sieve No.	Richardson's Gradings[a]		Forrest's Permissible Grading[b]
		Ideal for heavy traffic	Permissible for light traffic	
		Per cent	*Per cent*	*Per cent*
Dust	200	00.0	00.0	00.0
Fine	100	17.0		
	80	17.0		
		Total 34	26.0	20 to 30
Medium	50	30.0	30.0	
	40	13.0	13.0	
		Total 43	43.00	Not over 40
Coarse	30	10.0		
	20	8.0		
	10	5.0		
		Total 23	30.0	20 to 30
Very coarse	8	0.0	0.0	Not over 10
		Total 100	100	100

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[a] Byrne, A. T., A treatise on highway construction, p. 246, New York, J. Wiley & Sons, 1913.

[b] Forrest, C. N., Chief Chemist, Barber Asphalt Paving Co., in private letter dated August 17, 1917. From Baker, I. O., op. cit., p. 425.

[3] Baker, I. O., A treatise on roads and pavements, p. 418, New York, J. Wiley & Sons, 1920.

TABLE 6.—*Average grading of sands recently used in sheet asphalt pavements*[a]

City	Fine sand			Medium sand			Coarse sand				Retained on No. 10
	Passing sieve No.		Total	Passing sieve No.		Total	Passing sieve No.			Total	
	100	80		50	40		30	20	10		
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Boston	13.2	15.8	29.0	42.0	15.8	57.8	6.6	4.0	2.6	13.2	
Buffalo	16.7	12.5	29.2	34.7	9.7	44.4	5.5	4.2	9.7	19.4	7
Chicago	20.6	21.9	42.5	43.6	6.4	50.0	2.5	2.5	2.5	7.5	
Kansas City	26.3	19.2	45.5	23.4	8.9	32.3	8.9	8.9	4.4	22.2	
Louisville	16.4	11.0	27.4	35.6	17.8	53.4	9.6	5.5	4.1	19.2	
New York	14.6	13.3	27.9	37.5	17.3	54.8	9.3	5.3	2.7	17.3	
Omaha	9.2	17.2	26.4	51.1	7.9	59.0	5.3	5.3	4.0	14.6	
St. Louis	20.5	19.2	39.7	37.1	8.2	45.3	6.8	5.5	2.7	15.0	
Richardson's Ideal	17.0	17.0	34.0	30.0	13.0	43.0	10.0	8.0	5.0	23.0	

[a] Compiled from Richardson's Modern Sheet Asphalt Pavement, p. 331, 1913, by Baker, I. O., op. cit., p. 426.

be stated as a general fact because successes and failures have been recorded with both classes of sand".[4] The size of sand used is very essential to the most satisfactory results from a pavement. Table 5 shows the standard gradings for sand for the wearing course of sheet asphalt pavements and Table 6 some of the gradings of sand actually used for paving in various cities by the Barber Asphalt Company.

ASPHALTIC CONCRETE PAVEMENTS

This pavement consists of a concrete foundation with a wearing course of asphaltic concrete, composed of asphalt cement and broken stone with or without sand. It is desirable that sand, if used in this type of pavements, be free from impurities such as shale or clay, and consist of clean, hard grains. The grading of the sand should be approximately the same as for the wearing course of sheet asphalt pavement.

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[4] Agg, T. R., The construction of roads and pavements, 2d ed., p. 306, New York, McGraw Hill Book Co., 1920.

ASPHALT BLOCK PAVEMENTS

This type of pavement consists of blocks of prepared asphalt laid on a foundation of concrete, macadam or gravel. The blocks are 12 by 5 by 3 to 5 inches in size and are made by compressing in molds a mixture similar to that used for making the wearing course of sheet asphalt pavement. However, sand is not used by some manufacturers of asphalt blocks as it is reported to cut the molds.[5]

Sand for Asphaltic Flooring

Asphaltic flooring made of sand, a fine filler and an asphalt mastic, is sold under various trade names. When this type of flooring is to be used in government buildings, the sand aggregate must meet the following specifications issued by the Federal Specifications Board:

"The mineral aggregate shall be sand and small gravel. It shall be clean. hard grained and free from clay, silt, organic and other foreign matter, and shall be properly graded from coarse to fine, so as to produce a mixture of greatest density and stability. It shall fall within the following limits:

	Per cent
Passing a No. 3 screen	100
Total passing a No. 8 screen, not over	60
Total passing a No. 30 screen, not over	40
Total passing a No. 100 screen, not over	7.5"

Backing Sand *(See molding sand, pp. 125-130)*

Sand as a Ballast for Ships

Sand is sometimes carried by ships as ballast. The most desirable feature such sand can possess, is that it be of commercial value at the port of discharge.

Banding Sand

Banding sand is the name applied to a special type of abrasive sand. It is used to some extent for grinding plate glass but its most important use is for beveling the edges of plate glass.

Like any other abrasive sand, banding sand should consist of tough, hard, durable grains, and should be free from impurities and foreign material. The grains may be rounded or angular. The sand should be well graded. A Pennsylvania glass company specifies that banding sand be a high silica sand, white in color and of such size that 98 per cent will pass 30 mesh, 20 per cent be retained on 60 mesh, 50 per cent on 120 mesh, and 20 per cent on 200 mesh

The St. Peter sandstone makes a very suitable banding sand and is commonly used and sold for that purpose.

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[5] Richardson, Clifford, The modern asphalt pavement, p. 29, New York, J. Wiley & Sons, 1913.

Sand Bedding for Stock Cars

Sand for this purpose should be free from clay and pebbles, and be open enough to permit ready drainage.

Bird Grit *(See poultry grit, p. 134)*

Brass Sand

In making molds for casting brass, bronze and aluminum, a very fine sand, known commercially as brass sand, is used. The chief requirements of this sand are that it be very fine and sufficiently refractory to withstand the temperatures involved in casting. Since these temperatures are less than those to which steel molding sands are subjected, fine St. Peter is a suitable sand.

Sand for Clay Brick

Sand is used as a constituent of clay bricks to prevent contraction, shrinkage and cracking during burning and cooling and to give the brick a durable surface. It is also used for molding, facing and setting brick. (See parting, facing and setting sand, pp. 131, 113, 139.)

Sand for clay brick should in general be between 30 and 120 mesh[6] and well graded. Both angular and rounded sands are used, though the former are generally preferred. The sands should be free from soluble salts which will cause fusion of the brick during burning or efflorescence after burning. They should also be free from any substances which will give the brick an undesirable color.

The St. Peter sand is produced clean and in graded sizes and is, therefore, well suited for use in clay brick.

Sand for Brick Molding

Sand is used for dusting or sanding brick molds to prevent the brick from sticking to the molds.

Such sand should be fine, and free from clay. When used for sanding molds for silica brick it is essential that it should not differ radically in chemical composition and physical characteristics from the brick.

Because of its refractoriness and cleanness, and also because it can be secured in well-sized, fine grades, the St. Peter sand is very suitable for brick molding. One company using St. Peter sand for sanding molds in the manufacture of silica brick requires sand which will meet the following specifications:

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[6] Searle, A. B., Sands and crushed rocks, vol. 2, p. 3, London, 1923.

			Per cent
Size of grain	100 per cent must pass a 20-mesh sieve Not more than 10 per cent shall pass a 100-mesh sieve		
Color	Preferably white or buff		
Shape of grains	Round		
Chemical analysis	Silica	Minimum permissible	97.5
	Alumina	Maximum permissible	0.5
	Lime	Maximum permissible	0.5
	Magnesia	Maximum permissible	0.5
	Iron oxide	Maximum permissible	0.5
	Loss on ignition	Maximum permissible	1.0
Melting point	Minimum permissible	3065° F. (1685° C.) Orton cone 31.	

Sand for Silica Brick

Most silica brick are made from crushed quartzite or crushed flint, bonded by clay or lime. The chief objection to sands for this purpose is that they are often too low in silica content and too fine grained, and contain an excess of fluxing impurities. Three types of refractory brick are made, of which sand is one of the principal constituents, namely sand-brick, semi-silica brick and sand-bauxite brick.[7] These bricks are, however, only moderately refractory. Sand for refractory brick should contain from 96 to 98 per cent silica and should be free from organic material and dirt.[8] The total amount of alkalies present should not commonly exceed 2 per cent. Small amounts of iron and alumina, if the latter occurs as clay, are not harmful.[9]

Sand for Sand-lime Brick[10]

Sand-lime bricks are made by mixing about nine parts of sand with one part of slaked lime, pressing the resulting mixture into bricks and curing them in steam. A chemical reaction occurs between the sand and the lime and produces hydrated calcium silicate, which is the bond of the brick.

Sand for sand-lime brick should consist of both rounded and angular particles and should be composed of grains of various sizes. About 15 per cent of the sand should pass a 100-mesh sieve. Clay when not in excess of 10 or 12 per cent is generally not injurious to the brick, but for most sand-lime brick, a clean, siliceous sand is preferred.

The St. Peter sand is well suited for use in the manufacture of sand-lime brick because it consists of quartz grains, both angular and rounded, and can be obtained in graded sizes.

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[7] Searle, A. B., op. cit., pp. 144 and 145.

[8] Idem, p. 147.

[9] Additional references are:
Moore, E. S., and Taylor, T. G., The silica refractories of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Bull. M3, 1924.
Ross, D. W., Silica refractories: U. S. Bur. Standards, Technologic Paper 116, 1919.

[10] Sand-lime brick, description and specification: U. S. Bur. of Standards, Circular 109, p. 4, 1921.
Parr, S. W. and Ernest, T. R., A study of sand-lime brick: Illinois State Geol. Survey Bull. 18, p. 42, 1912.

Brick Pavements

GENERAL STATEMENT

The two types of brick pavements now in use are known as "monolithic" and "semi-monolithic". The latter type consists of a cement concrete base or foundation, a bedding course of sand or sand-cement, and the wearing course of brick. The joints between the bricks are filled with sand, a grout of cement and sand, or a bituminous filler. The monolithic type consists of a base course of concrete into which the brick are laid and pressed before it sets. Cement mortar is used as grout.

The specifications for sand used in both types of brick pavements are essentially the same and will be described without reference to the type of pavement.

CEMENT CONCRETE BASE

Sand enters into this part of the pavement only in the fine aggregate most of which is quartz sand; it may also be rock screenings. The sand should consist of clean, uncoated, hard, durable grains and be free from organic material, friable fragments, such as shale or slate, and "shall not contain clay or silt in excess of five per cent by weight".[11] The specifications of the Illinois Division of Highways[12] are a little more stringent and require that the "fine aggregate shall not contain over two (2.0) per cent of material removed when tested by the Elutriation test."

The Illinois Highway Department specifies further that not less than 95 per cent should pass a ¼-inch sieve; not less than 35 per cent or more than 70 per cent 20 mesh; not more than 20 per cent 50 mesh; and not more than 5 per cent 100 mesh.

BEDDING COURSE

SAND

The sand bedding course consists of a layer of sand between ½ and 1 inch thick when finished, onto which the brick making the wearing surface are laid. Sand for this purpose "shall not exceed one-quarter inch in maximum grain size. It may contain fine material passing a No. 20 standard mesh sieve, not exceeding fifteen per cent by weight."[11] This fine material may be loam or clay. The specification of the Illinois Division of Highways for bedding sand is the same as that for fine aggregate.

SAND-CEMENT

The sand-cement bedding course consists of a layer of dry sand and Portland cement mixed in the ratio of 1 to 4. The layer when finished should

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[11] Specifications, National Paving Brick Manufacturers Assoc., 1924.

[12] Standard specifications for road and bridge construction, Illinois Division of Highways, pp. 28, 63, 67, Nov. 1, 1924.

be between ½ and 1 inch thick. The brick are set on this sand-cement bed and the pavement is then sprinkled. Sufficient water trickles between the brick to wet the sand-cement bed and to cause it to set. Sand for this purpose should pass a ¼-inch sieve, be of uniform size, and clean. It should be "free from soft, friable material, shale or slate, vegetable or other organic matter. It shall not contain clay or silt in excess of five (5) per cent by weight."[11]

JOINT FILLER

SAND

Sand for this purpose must be clean, dry, free from flaky particles and "of such sizes that all will pass a No. 12 sieve".[11]

CEMENT GROUT

Cement grout filler consists of 1 to 2 or 1 to 3 parts of Portland cement and sand respectively. Sand used in cement grout should consist of clean, hard, sharp, uncoated grains and should not contain "more than two (2) per cent of material which may be removed by the Elutriation test".[12] Other specifications state that the sand shall not contain clay in excess of five (5) per cent. The Illinois Highway Department specifies that the sand shall be well graded from coarse to fine and that "not less than 95 per cent shall pass a 10 mesh sieve, not less than 75 per cent 20 mesh, not more than 30 per cent 50 mesh, and not more than 10 per cent 100 mesh".[12] The National Paving Brick Manufacturers Association recommends sand of such size that "100 per cent will pass a No. 12 sieve, not more than 40 per cent a No. 50 sieve, and not more than 6 per cent a No. 100 sieve".[11]

BITUMEN

This type of filler may be tar or asphalt. Sand is not commonly employed but it is used merely to surface the filled joints to prevent the bitumen from sticking to the wheels of passing vehicles. Sand which passes inspection as fine aggregate is used.

ST. PETER SAND FOR USE IN BRICK PAVEMENTS

The St. Peter sand, except when badly coated with iron hydroxide, will furnish a high-grade paving sand. It possesses inherently the very desirable properties of cleanness and hardness, and though some parts of the formation are probably a little too fine, the sand of the deposit as a whole is of such size as to pass the specifications stated above.

Burnishing Sand[13]

For rolling down and burnishing gold decorations on china and porcelain, a fine-grained, high silica sand called "burnishing sand" is employed.

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[13] Stone, R. W., Sand and gravel: U. S. Geol. Survey Mineral Resources, 1912, pt. 2, p. 630, 1913.

This type of sand should consist of clean, tough, rounded grains. The sand used commercially is uniform in size and practically all of it passes 65 mesh but is retained on 100 mesh.

SAND FOR THE MANUFACTURE OF CARBORUNDUM

Chemically, carborundum is known as silicon carbide. It is made by fusing sand, coke, sawdust and salt in an electric furnace. The sand makes up about half of the furnace charge and the coke about a third. The chemical equation describing the principal reaction taking place in the furnace is as follows:

SiO_2 (sand) + 3C (coke) → SiC (silicon carbide) + 2CO

The most important specification for sand to be used in making carborundum is that it be a high silica sand. The sand should, therefore, be free from clay, organic material and other impurities. The shape of the grains is unimportant. It is desirable that the sand be graded to remove lumps and overly large grains. One company specifies that sand for carborundum be white, contain over 99.5 per cent silica and be of such size that 100 per cent will pass 24 mesh and 100 per cent be retained on 128 mesh.

The high silica content of the St. Peter sandstone makes it very desirable for use in the manufacture of carborundum.

SAND FOR CEMENTS[14]

Sand is used in the following types of cements; its function is chiefly that of an inert filler.

Sand cement	an intimate mixture of sand and cement made by grinding the two together.
Oxychloride cement	a mixture of fine sand and magnesium oxychloride.
Borax cement	a mixture of fine sand and borax.
Lead cements	a mixture of sand with white lead or litharge, lime or plaster of Paris, and linseed oil.
Dental cement	a mixture of ground sand, zinc oxide, borax, and zinc chloride.

No specifications are available for the sand used in the cements enumerated above, but in general a high silica sand, ground to 100 or 200 mesh is used.

SAND FOR CHEMICAL PURPOSES

Sand is used in the preparation of a number of chemical compounds other than those mentioned specifically elsewhere in the text. In general it should be fine-grained and very pure.

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[14] Eckel, E. C., Cements, limes and plasters; their materials, manufacture, and properties, 2d ed., p. 537, New York, J. Wiley & Sons, 1922.
Searle, A. B., Sands and crushed rocks, vol. 2, p. 42, London, 1923.

COKING SAND[15]

In the manufacture of coke, sand is sometimes added to the charge of the retorts or ovens to combine with any bases present. Sand for this purpose should be fine and high in silica.

SAND FOR CONCRETE

In general, sand consisting principally of quartz grains is used as the fine aggregate for concrete. Specifications for sand for this purpose vary somewhat but agree that it should be clean, free from oily or organic matter, dust, earth, clay, shale particles. mica, ochre or other soft grains, and shall consist of hard, strong, uncoated grains. Specifications also require that a 1 :2 to 1 :3 mortar made of Portland cement and the sand shall have a compressive strength at the end of seven and twenty-eight days respectively, at least equal to that of a mortar made from the same cement and Ottawa standard sand.

The following specifications give an idea of the variation permitted in the size of the grains composing the fine aggregate.

Illinois Highway Department[16]

Passing ¼-inch sieve	not less than 95%
Passing 20-mesh sieve	35 to 70%
Passing 50-mesh sieve	not more than 20%
Passing 100-mesh sieve	not more than 5%

California Highway Engineers[17]

Passing a ⅜-inch sieve	100%
Passing a No. 3 sieve	not less than 95%
Passing a No. 4 sieve	85 to 95%
Passing a 30-mesh sieve	15 to 35%
Passing a 100-mesh sieve, including silt and clay	not more than 5%

Engineers Society of Western Pennsylvania[18]

Fine sand:

Not over 0% shall be retained on a No. 4 sieve
Not over 15% shall be retained on a No. 8 sieve
At least 85% shall be retained on a No. 50 sieve
At least 94% shall be retained on a No. 100 sieve

Coarse sand:

not over 9% shall be retained on a ⅜-inch sieve
Not over 15% shall be retained on a No. 4 sieve
At least 70% shall be retained on a No. 50 sieve
At least 94% shall be retained on a No. 100 sieve

Tyler Standard Sieves to be used. Weight removed by decantation test made according to A. S. T. M. method. Serial Designation D 136-22T, shall not exceed 3%.

Because of the inherent hardness and cleanness of the grains of the St. Peter sand, except where badly stained by iron, it is very satisfactory for con-

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[15] Searle, A. B., op. cit., p. 228.

[16] Standard specifications for road and bridge construction, Illinois Division of Highways, Nov. 1, 1924.

[17] McKesson, C. L., Materials and research engineer for the California Highway Commission), Standardization of Specifications for sand, rock and gravel : Rock Products, vol. 28, No. 4, p. 62, Nov. 28, 1925.

[18] Tentative specifications for aggregates, Civil Section of the Engineers Society of Western Pennsylvania, Sept. 17, 1925.

crete work. As it occurs naturally it rarely contains more than the permissible amount of clay, but some of it is a little too fine to meet specifications. Inasmuch as the sand is produced commercially in sizes which meet specifications, it is readily available for concrete purposes.

CORE SAND *(See molding sand, pp. 125-130)*

SAND FOR CUSPIDORS

Earthenware jars filled with white sand are used in many hotels and public buildings as waste receptacles and cuspidors. The principal requirement of the sand used for this purpose is that it be white and clean. The St. Peter sand is admirably suited inherently for this purpose and is widely used.

CUTTING AND SAWING SAND

Sand is commonly used as an abrasive in cutting and sawing stone. It is applied with water directly to the cutting or sawing blade.

DESIRABLE PROPERTIES

1. It is desirable that the grains be of approximately the same size, or within a given size range, in order that the maximum cutting efficiency may be secured. If the grains are of unsorted sizes, the larger grains alone support the cutting edge of the blade and do the cutting work, whereas the smaller grains are practically inert, and may possibly be detrimental to obtaining maximum speed in cutting.

The texture of the sand used varies with the preferences of different consumers and is probably partly dependent on the texture of local supplies. One marble company using St. Peter sand specifies a sand which will pass 30 mesh and be retained on 50 mesh. Another marble company[19] uses washed river sand of which 3.7 per cent is retained on 10 mesh; 12.6 per cent on 20 mesh; 83.8 per cent on 48 mesh; and 98.6 per cent on 100 mesh. Still another analysis[19] of sawing sand shows 0.4 per cent retained on 20 mesh; 79.6 per cent on 35 mesh; and 99.6 per cent on 65 mesh. A stone plant in Illinois specifies the following for cutting and sawing sand: 75 per cent should pass 30 mesh, and 85 per cent to be retained on 40 mesh. And finally the Bedford Stone Club representing the Bedford stone industry of Indiana specifies, "hard, white silica sand, thoroughly washed and free from all foreign matter; dried and screened so as to remove all dust and fine particles; and testing between 80 and 85 per cent, remaining on a 40-mesh screen".[20]

2. The shape of the sand grains used is also a matter of preference and of the character of the grains of local supplies of sand. Both angular and

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[19] Weigel, W. M., Special sands: U. S. Bur. Mines, Serial 2646, October, 1924.
[20] Personal communication, Dec., 1924.

rounded sands are used; some companies state that they prefer the rounded grains and others the angular grains.

3. In a pure quartz sand all the sand grains will be of about the same hardness. If grains of other minerals besides quartz are present in the sand, they should be of a hardness equal to or greater than that of quartz. Softer material is of doubtful value and may possibly be harmful. A quartz sand is generally preferred.

4. The color of a sand is not generally essential provided that the coloring material will not stain or result in stains in the stone being worked.

5. The sand grains should be hard and free from incipient fractures which might result in easy breakage of the grains.

6. The sand should be free from clay and organic material since these are of no value and may cause clogging of feed pipes.

7. The chemical analysis of cutting and sawing sand is not generally important except as it shows the approximate quartz content of the sand and suggests what minerals are present as impurities.

ST. PETER SAND AS CUTTING AND SAWING SAND

The St. Peter sand is extensively used as cutting and sawing sand. After it has been washed and screened, it possesses all the desirable properties of sand for this purpose.

Sand for Dental Purposes

Ground sand or silica is used by dentists as a detergent or abrasive.

Sand for Dispelling Fog[21]

The United States government is experimenting with electrically charged sand scattered by aeroplanes as a means of dispelling fogs and clouds over harbors. The sand used is 120-mesh silica sand. It is claimed that two large planes could eliminate fog over an area of 117 square miles or more.

Sand for Enameling[22]

In the preparation of enamels for applications to metal objects, quartz sand and ground quartz sand are used as constituents and sometimes as a partial substitute for feldspar. The sand is commonly used in the preliminary or "ground" coat given the metal and the ground quartz sand in the finish or "cover" coat. The use of quartz in the proper proportion in an enamel is said to give it additional hardness and resistance to attack by acids.

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[21] The newest use for fine sand: Rock Products, vol. 27, No. 24, p. 55, Nov. 29, 1924.

[22] Grunwald, J., Raw materials for the enamel industry, p. 16, London, 1914.
Stanley, H. F., Materials and methods used in the manufacture of enameled cast-iron wares: U. S. Bur. Standards, Technologic Paper 142, pp. 20-22, 1919.

Sand to be used in enamels should be free from clay and contain more than 97 per cent silicon dioxide (silica). It should not contain more than 0.32 per cent ferric oxide, since iron imparts a color to the enamels which is undesirable. For the ground coat a sand comparable in size to a high-grade glass sand is commonly preferred. Finely pulverized sand is used for making the cover enamels.

Because of its purity and because it is produced in sizes suitable for use in making enamels, the St. Peter sand is well adapted for this purpose.

Engine Sand

Engine sand is used to increase the traction of and so prevent slipping of the driving wheels of railroad locomotives, electric cars, and mine locomotives. It is also known as traction or trolley sand. It is applied to the rails from a pipe connected to the sand dome or box.

So far as could be ascertained, there are no detailed specifications for engine sand. Four railroad companies to whom inquiries were sent replied that they had no specifications for the sand. The matter of prime importance is commonly the availability of the commodity to the supply point of the consumer. It is important, however, that engine sand be clean and dry. In general a rather uniformly graded, medium fine sand is preferred. The sand should be free from small twigs, leaves and other foreign matter which might clog the sand pipe or valve, and should not contain large amounts of clay or other material which might absorb moisture and thus tend to form lumps in the sand. A high silica sand is generally desirable. Both rounded and angular sands are used.

Since the St. Peter sand is composed of hard, durable grains and can be purchased clean and dry in well-graded sizes, it makes a very satisfactory engine sand and is rather commonly used in Illinois, at least, for this purpose.

Sand for Erasers

Sand is used as an abrasive in certain types of rubber erasers for rapid, rough work. A fine, angular, sharp sand is desirable for this purpose.

Sand for Explosives[23]

Sand is sometimes used as an absorbent for nitroglycerine in the manufacture of dynamite and other nitroglycerine explosives. Any common sand which is composed of rounded grains of uniform size and which is fine enough to pass a 30-mesh sieve is suitable for this purpose.

Facing Sand and Silica Mold Wash for Foundry Use

In order to give castings a smooth surface, molds are commonly dusted or washed with fine silica. In making very high-grade castings, sand as fine

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[23] Searle, A. B., Sands and crushed rocks, vol. 2, p. 236, London, 1923.

as 250 mesh is sometimes used. The practice is, however, to use as coarse a sand as is consistent with the character of the casting and surface desired, inasmuch as very fine facing sand tends to clog the surface of the mold and thus decrease its permeability. For facing molds for steel castings ground sand passing a 200-mesh sieve is commonly used. St. Peter sand is widely used as a mold wash and facing sand. The specifications of the United States Navy Department for silica mold wash are as follows:

50S1
Jan. 1,
1920

NAVY DEPARTMENT SPECIFICATIONS
SILICA MOLD WASH

(for Steel Foundry use)

General Instructions.

1. The material desired under these specifications is a pure silica flour, very finely powdered and air floated to remove such particles as will separate in a water emulsion.

Chemical Requirements.

2. The powder shall show an analysis not less than *99* per cent dehydrated silica &(SiO_2).

Physical Requirements.

3. *100* per cent of the powder shall pass through a sieve having *200* meshes to the the linear inch.

4. A 5-gram portion shall be placed in a *100*-cubic centimeter graduated comparison tube and the volume brought to *100* cubic centimeters by the addition of cold water. After thorough agitation and mixing, *1* cubic centimeter of sediment shall settle to the bottom of the tube in not less than 10 minutes.

General Requirements.

5. The material shall be suitable for use in steel foundry work by mixing with water or binder mixture for washing the surfaces of sand molds.

Samples.

6. Bidders shall supply samples of material they propose to furnish.

SPECIFICATIONS, WHERE OBTAINABLE.

Note.—Copies of the above specifications can be obtained upon application to the Bureau of Supplies and Accounts, Navy Department, Washington, D. C.

References.

Comdt. & Supt. Nav. Gun Factory, Nov. 8, 1919.
S. & A., 380-1411

149559—19

Washington: Government Printing Office: 1919

Sand for Facing Tile and Brick

In order to obtain certain architectural or artistic effects, some face-brick and roofing tile are given a face-coat of sand. The sand is applied to the brick or tile before burning.

In general the size of the sand used for facing brick and tile depends on the preference of the maker. A medium sized sand is very commonly used. If the brick or tile is red it is desirable that a small amount of iron oxide be present in the sand so that it will be red after burning and match the brick. If a white brick is being manufactured, however, the sand should be free from iron compounds which might discolor the brick either during burning or when in the wall.

The St. Peter sandstone furnishes various grades of sand, some of which contain sufficient iron to burn red or yellow; the washed product burns white.

Sand for Making Ferro-silicon and Other Silicon Alloys[24]

Ferro-silicon is made by heating a charge of quartzite or sand, carbon (coke, anthracite or charcoal) and iron or steel turnings in an electric furnace. The reaction is as follows:

$$SiO^2 + 2C + Fe \rightarrow (Fe.Si) + 2CO$$

Other alloys are made in the same way by substituting other metals for part of the silica and iron.

The chief specification for sand to be used for making silicon alloys is that it be fine, free from foreign material and more than 95 per cent silica. In general lime and alumina are to be avoided. Because the St. Peter sand is chemically very pure and can be produced in fine sizes, it should be suitable for the manufacture of silicon alloys.

Sand as a Fertilizer Filler

Because of its inherent loose and incoherent character, sand is used as a filler for fertilizer. The sand prevents hardening and keeps the fertilizer in a mealy condition. No specifications are known for sand for this purpose but it seems probable that any clean, medium or fine sand would be suitable.

Sand as a Filler

Sand, usually in the ground form, is used as a filler for rubber, paper, soap and linoleum. It is also used for filling defects in the surface of wood prior to finishing painting, when it is commonly mixed with a small amount of oil as a binder.

Sand for Filling Mines

Sand is sometimes used for filling parts of worked out portions of mines to prevent the collapse of the mine roof. No specifications are available for sand for this purpose.

Filter Sand

The growth of the American cities and the consequent necessity of an increased supply of water have led to the use of surface water to fulfill the demand. The sand filter is commonly employed for freeing surface water from dirt, organic matter, metallic oxides and salts, and bacteria. It is also used for removing metallic oxides and salts from well waters. A sand filter consists of layers of materials of different sizes, beginning with coarse gravel

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[24] Martin, Geoffrey, Industrial and manufacturing chemistry, pt. 2, Inorganic, p. 407, New York, D. Appleton & Company, 1918.
Colony, R. J., High-grade silica materials for glass, refractories, and abrasives: New York State Museum Bull. Nos. 203, 204, p. 26, 1917.
Searle, A. B., Sands and crushed rocks, vol. 2, p. 184, London, 1923.

at the bottom and grading upward to the sand bed which is at the top of the filter. Commonly the lower 12 or 18 inches of the filter is composed of gravel layers, and the upper two or three feet of sand.

A number of specifications for filter sand are available. Each varies somewhat from the others but the following items are essentially the same for all sets of specifications:

1. General physical properties—The sand shall be clean and free from organic material. It shall consist of hard, impermeable grains, either rounded or somewhat angular but not flat, sharp, or splintery. The color of the sand is unimportant.

2. Size of grains—The effective size (p. 155) of the sand may vary from 0.3 to 0.7 but for municipal work is usually required to be between 0.35 and 0.45. The uniformity coefficient varies between 1.5 and 2.0 but is ordinarily about 1.6 for sand used in municipal filters.

3. Chemical properties—Filter sand should be composed principally of insoluble grains. This property is tested by allowing some of the sand to stand for 24 hours in a concentrated solution of hydrochloric acid. The loss in weight should not exceed 5 per cent and commonly a loss not to exceed 3 per cent is specified.

The St. Peter sand of the Ottawa district has long been used as a filter sand. The physical and chemical properties of the sand made it especially suited for this purpose, except that the crude sand is in general said to be somewhat too fine to be an ideal filter sand.

Fire Sand *(See furnace sand, p. 117)*

Floor Sand *(See molding sand, pp. 125-130)*

Sand as a Flux in Metallurgy

Silica sand is sometimes used in the smelting of sulphide lead and copper ores as a flux which will combine with the iron present to make a slag. It is also used in the treatment of coarse metal copper mattes for white metal.[25]

Inasmuch as the silica content of the sand is of first importance, it is desirable that the sand for metallurgical purposes be a high silica sand. The size of the grain is not of great importance, though a fine sand is generally preferred. Because of the high silica content and fineness of grain in which the St. Peter sand can be produced, it is a very high-grade metallurgical sand.

French Sand

"French sand is a very fine, open, sharp, yellow sand imported from France used for making molds for statuary, brass and bronze work".[26]

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[25] Schnabel, Carl, Handbook of metallurgy, vol. 1, pp. 140 and 284, 1898.

[26] Stone, R. W., Sand and gravel: U. S. Geol. Survey Mineral Resources 1912, pt. 2. p. 631, 1913.

FRICTION SAND

Friction sand is any sand used for the purpose of creating greater friction between two objects. The term is used synonymously with engine sand, but includes also sand used for increasing the friction between pulleys and belts and other similar devices. A rather fine, well graded sand is used for this purpose.

SAND FOR MAKING FUSED SILICA[27]

Fused silica, also known as silica glass or fused quartz, is commonly made from crushed crystalline quartz. However, the fusion of very pure silica sands such as the washed St. Peter sand gives a variety of fused silica which possesses most of the qualities of the glass made from the crystalline quartz except that numerous small bubbles are included in it. The glass made from the silica sand is very uniform and it is possible that it may find considerable economic application because it is not permeable to liquids or gases and is not affected by sudden heating and cooling. Crushed fused silica is coming to be of increasing interest as a ceramic material and it is possible that St. Peter sand will be an acceptable raw material for manufacturing fused silica for this purpose.

FURNACE AND FIRE SAND

The terms furnace sand and fire sand are used synonymously to describe sand for making the bottom or bed of metallurgical furnaces and when mixed with small amounts of fire clay or lime to line the walls. Sand for these purposes is also used in the hearths of steel, malleable iron, and copper furnaces, and with a binder as a lining for converters, cupolas, and ladles for holding molten metal.

The chief property that fire sand should possess is high refractoriness. Therefore, a high silica sand, free from fluxing impurities and organic material is desirable. A small amount of clay or iron hydroxide which may serve as a bond to hold the sand together in the hearth is said to be desirable. The size of the sand used seems to be somewhat arbitrary and to depend largely on the most convenient source of sand supply. The material is generally finer than 10 mesh, however. The use of rounded or angular sands seems also to be arbitrary. Angular sands will stand at a somewhat steeper angle in the sides of the furnace bed than rounded sands but do not make as compact a bottom.

The St. Peter sand, especially that produced by the molding sand companies, is sold as fire or furnace bottom sand. It is very satisfactory because it contains small amounts of bonding material and is highly refractory. Below is the sieve analysis of sand from the Utica district sold as furnace bottom sand:

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[27] Thomson, E, Mechanical and other properties of fused silica: Cement, Mill and Quarry, vol. 27, No. 6, pp. 34-44, Sept. 20, 1925.

	Per cent
Through 28 mesh on 35 mesh	9
Through 35 mesh on 48 mesh	32
Through 48 mesh on 65 mesh	19
Through 65 mesh on 100 mesh	20
Through 100 mesh on 150 mesh	14
Through 150 mesh	6

Glass Sand

Quartz sand (SiO_2) is an important constituent of most glasses and constitutes from 50 to 65 per cent of the raw mix. It is known commercially as glass or melting sand. There are many different kinds of glasses. The following classification indicates the different types and their general composition.

TECHNICAL CLASSIFICATION OF GLASSES[28]

The glasses of chief importance may conveniently be classified as follows:

1. Polished plate embraces all glass cast upon a smooth table, rolled to the required thickness with a roller, annealed, and then ground and polished.
2. Rough plate embraces all glass cast as above, but not ground and polished. The principal varieties are ribbed plate, colored cathedral, rough plate, wire glass and heavy rough plate for skylights.
3. Window glass embraces all glass blown in cylinders, and afterwards cut, flattened out and polished while hot. Chiefly used for glazing, pictures, mirrors, etc.
4. Crown glass embraces glass blown in spherical form and flattened to a disk shape by centrifugal motion of blow pipe. A little is made at the present time for decorative purposes.
5. Green glass embraces all the common kinds of glass, and is not necessarily green in color. It is used in the manufacture of bottles, carboys, fruit jars, etc.
6. Lime flint embraces the finer grades of bottles used for the prescription trade, tumblers, certain lines of pressed tableware and novelties.
7. Lead flint embraces all the finest products of glass making such as fine cut glass, table ware, optical glass, artificial gems, etc.

IMPURITIES IN GLASS SAND

The most common impurities found in glass sands are iron, clay materials, magnesia, earthy and organic material. These impair the transparency, brilliancy or hardness of the glass. Iron colors the glass green, yellow, or brownish, depending on the amount and chemical character of the iron compounds present. The iron in glass sands may occur as a thin film or coating on the grains of sand or as iron minerals such as pyrite, magnetite, ilmenite, or

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[28] Linton, Robert, Glass: Min. Industry for 1899, vol. VIII, New York, pp. 234-263, 1900.

the like. The magnetic minerals may be removed by passing the sand over a magnetic separator, but the non-magnetic types cannot be commercially removed and consequently a sand containing more than the allowable amount of these minerals must be avoided.

Alumina in small amounts is said to induce desirable properties in a glass. It is present in glass sand chiefly as clay, feldspar or white mica.

Lime, magnesia, and other alkalies are generally avoided in sand for high-grade glasses in order that careful and certain control may be kept on the composition of the raw materials entering a glass mix.

SHAPE OF SAND GRAINS

Theoretically an angular sand should melt faster than a rounded sand composed of grains of nearly the same size, because the angular sand has a greater theoretical permeability and exposes more surface to heat in proportion to its volume than does the rounded sand. Practically, however, it has been found that the shape of the sand grains is a comparatively unimportant factor in influencing the melting temperature; in fact some glass manufacturers specify sand with rounded grains.

SIZE OF SAND GRAINS

There are many different opinions as to what size sand is most desirable for glass making. A fine sand melts more readily than a coarse sand but is reported to yield less glass per unit volume than a coarse sand. In a mixture of fine and coarse sand the fine material may settle to the bottom of the batch and result in a glass of uneven texture. In general a sand which is a compromise between fine and coarse is used for making glass and the specifications which follow indicate the general latitude in size allowable in a glass sand.

PROPOSED TENTATIVE SPECIFICATIONS FOR SILICA SAND FOR GLASS-MAKING[29]

The following are the tentative specifications for glass sand prepared by the Committee on Standards of the Glass Section of the American Ceramic Society in cooperation with the Bureau of Standards.

GENERAL

1. Character of sand.—Sand as commonly used for glass-making purposes is a white, clean, dry, fine-grained quartz, washed practically free from all clay-like material and other impurities. The chief criterion for a good glass sand is that it should be practically all silica and contain very little iron.

In view of the increasing use of alumina in a glass batch and of the varying amounts of iron allowable in green or amber glass, sand of lower grade

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[29] Bull. Amer. Ceramic Soc., vol. 2, No. 3, pp. 182-183, March, 1923.

may be used by many manufacturers. These specifications, therefore, will show a variety of qualities and state more or less definitely the types of glass they may be used for. The quality number is not to be interpreted as necessarily being an index to the value of the product.

REQUIREMENTS

2. Packing.—Cars in which sand is to be shipped shall be thoroughly cleaned before loading, and lined with paper where sand is sold for first, second or third quality.

3. Impurities.—Sand shall not be contaminated with stripping dirt or contain any crushed stones or pebbles. These impurities are often insoluble in the melting glass, producing stones.

4. Screening and washing.—All sand shall be screened, washed and dried before shipment, except where the natural condition of the quarries will allow the production by screening only of fourth, fifth, sixth or seventh quality sand.

Table 7.—*Percentage composition of sands of various qualities based on ignited samples*

Qualities	SiO_2		Al_2O_3		Fe_2O_3		$CaO+MgO$	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
First quality optical glass		99.8	0.1		.02		0.1	
Second quality flint glass containers, tableware		98.5	0.5		.035		0.2	
Third quality, flint glass		95.0	4.0		.035		0.5	
Fourth quality sheet glass rolled and polished plate		98.5	0.5		.06		0.5	
Fifth quality sheet glass rolled and polished plate		95.0	4.0		.06		0.5	
Sixth quality green glass containers and window glass		98.0	0.5		0.3		0.5	
Seventh quality green glass		95.0	4.0		0.3		0.5	
Eighth quality amber glass containers		98.0	0.5		1.0		0.5	
Ninth quality amber		95.0	4.0		1.0		0.5	

5. Although sand may vary considerably in composition, depending on the type of glass to be made, the composition of any single quality specified shall not vary from shipment to shipment more than the amounts stated in Table 8.

TABLE 8.—*Percentage tolerances in composition allowed (based on ignited sample)*

Quality	SiO_2	Al_2O_3	Fe_2O_3	CaO+MgO	Rmx
1	±0.1%	±0.05%	+0.005%	±0.05	
2	±0.5	±0.1	+0.005	±0.05%	
3	±1.0	±0.5	+0.005	±0.1	
4	±0.5	±0.1	+0.005	±0.1	
5	±1.0	±0.5	+0.005	±0.1	
6	±1.0	±0.5	±0.05	±0.1	
7	±1.0	±0.5	±0.05	±0.1	
8	±1.0	±0.5	±0.1	±0.1	
9	±1.0	±0.5	±0.1	±0.1	

6. Sand shall be prepared so that the size of grains shall be rather uniform and be within the limits set in Table 9.

TABLE 9.—*Limiting per cents of various sizes of sand grains*

Through a No. 20 screen	100%
Through a No. 20 and remaining on a No. 40 screen	Not more than 60% nor less than 40%
Through a No. 40 and remaining on a No. 60 screen	Not more than 40% nor less than 30%
Through a No. 60 and remaining on a No. 100 screen	Not more than 20% nor less than 10%
Through a No. 100 screen	Not more than 5%

ST. PETER SAND AS A GLASS SAND

The St. Peter sand has long been known as a very high-grade glass sand. The washed and dried sand which is sold for making glass is very pure, high in silica and low in impurities including especially iron. Repeated analyses give the silica content as over 99.97 per cent. In general the magnesia varies from a trace to about 0.01 per cent, the lime content from nothing to 0.02 per cent, the iron oxide from nothing to about 0.02 per cent and the alumina from nothing to about 0.05 per cent.

As indicative of the requirements which the St. Peter sand meets the following specifications from companies using the sand are given:

Sand for making sheet glass:

All sand must pass 20 mesh and not over 2 per cent should pass 150 mesh. Sand from a given source should be uniformly sized. As far as practicable, it is desired that a negligible amount of the sand be finer than 100 mesh.

Sand for making plate glass:

100 per cent must pass 16 mesh, 98 per cent be retained on 120 mesh.

85 per cent must pass 30 mesh, 80 per cent be retained on 60 mesh.

The color of the sand must be white; the shape of the grains is unessential. The sand should meet the following chemical specifications:

		Per cent
Silica	minimum permissible	99.50
Alumina	maximum permissible	0.15
Magnesia	maximum permissible	0.10
Lime	maximum permissible	0.10
Iron oxide	maximum permissible	0.05

Sand for flint bottles:

100 per cent must pass 20 mesh; 34 per cent be retained on 40 mesh; 90 per cent be retained on 60 mesh.

Color must be white; rounded grains are preferred. The chemical analysis of the sand should pass the following specifications:

		Per cent
Silica	minimum permissible	99.05
Alumina	maximum permissible	0.05
Magnesia	maximum permissible	0.10
Lime	maximum permissible	0.05
Iron oxide	maximum permissible	0.04

Sand for Making Glazes

In the manufacture of such ceramic products as chinaware, porcelain, pottery, and stoneware, a glaze is applied to give the ware an impervious, smooth, glassy exterior. Silica is an essential constituent of these glazes which are really a glass.

In general a sand possessing the properties of a high-grade glass sand is used for making glazes. Such sands commonly contain less than 0.02 or 0.03 per cent of iron oxide, and very minor amounts of alumina and other oxides. The sand may be either purchased as the natural grain and ground by the consumer or obtained already pulverized. Commonly a product fine enough to pass through 120 to 140 mesh is used.

Since the St. Peter sandstone is a high-grade glass sand, it is a very suitable material for use in making glazes. The sand may be obtained as screened washed sand or as ground silica. It is most commonly sold by the Illinois plants in the ground form.

Sand for Golf Tees, Traps, Hazzards, and Greens

A clean, white, medium-grained sand is used for golf tees. Sand is also used for constructing various hazzards and traps, and sand greens in golf courses. A moderately clean sand is commonly specified for this purpose.

Grinding and Polishing Sand

Sand is commonly employed as an abrasive for the rough grinding of stone. The grinding is done on a rotating circular table known as the grinding bed, on to which the sand is fed with water. Sand is also used for smoothing and grinding sanitary ware, terra cotta, and other ceramic products. The process is carried out on a horizontal iron lap.

Another use for abrasive sand is in the grinding of a smooth surface on crude, rolled plate glass before it is given its final grinding and polishing. The sheets of glass as they emerge from the annealing oven have an undulating, opaque surface. They are set in a bed of Plaster of Paris and fastened with pegs to the grinding table which consists of a large rotatable iron platform. The table is then set in motion and sand and water fed upon the surface of the glass plate. The grinding is done by iron slabs or iron shod wood boxes which rest upon the glass. The slabs have a revolving motion of their own around a vertical axis.

A high silica sand, with tough grains, which is free from clay and other foreign material is desired for grinding and polishing. It is essential that the sand be well graded to remove large grains and debris which might clog the sand-circulating system. Large grains are also to be avoided because they produce deep scratches in the glass which may be difficult to remove in the final grinding and polishing. The shape of the grains is of minor importance as angular grains become rounded and rounded grains break to yield angular fragments. A large Pennsylvania plate glass company specifies rounded sand of which 100 per cent will pass 16 mesh, 98 per cent be retained on 120 mesh and 80 per cent on 60 mesh. A Michigan plate glass company specifies rounded sand, light gray or white in color, of which 100 per cent must pass 20 mesh, 40 per cent be retained on 40 mesh and 88 per cent on 60 mesh.

The St. Peter sandstone is very suitable for grinding and polishing since it is inherently a high silica sand with tough grains. The sand washed and sized by the plants at Ottawa is widely used for this purpose.

Sand for Grinding Wheels

Sand is used to some extent as the abrasive constituent of grinding wheels. These are made by mixing sand with clay, rubber, shellac or some other bonding substance. In general angular sand is preferred because the bonding matrix of the wheel holds the angular particles more firmly than the round ones, thus increasing the period of use of the wheel. An angular sand is also said to give a more rapidly cutting wheel.

Horticultural Sands

In propogating cuttings of plants and shrubs, horticulturists commonly employ a manured sand for the early growth of the cuttings. Another type of horticultural sand known as "potting sand" is mixed with about an equal amount of good loam and is used for raising plants in greenhouses and under glass. Sand is also used as an essentially sterile medium in which to grow plants in experimenting on the effect of different substances on growth, color, and characteristics. Another type of sand, known as "lawn sand" is used for improving the color and growth of lawns.

It is very important that sand for horticultural purposes be clean, well sized, and free from iron, clay and other impurities particularly those which might effect a bacterial contamination of the plant-growing medium. There are no definitely specified sizes for sand for horticultural purposes, but commonly a medium to coarse sand is used. The angularity or roundness of grain is generally of minor importance. A small sample of the St. Peter sand used for horticultural purposes by the Agricultural Department of the University of Illinois, screened as follows: 35 per cent retained on 40 mesh, 38 per cent on 60 mesh, 18 per cent on 100 mesh and 9 per cent through 100 mesh.

Screened St. Peter sand and especially that which has been washed, is a very satisfactory horticultural sand because of its general cleanness.

Hour-glass sand

Small amounts of fine, clean, well-graded sand are used in hour glasses. Sand consisting of rounded grains between 80 and 100 mesh is commonly specified for this purpose.

Sand for Use on Icy Streets and Walks

An increasing amount of sand is being used for sanding icy walks and pavements, particularly in hilly cities, in order to prevent pedestrians and vehicles from slipping. The sand is also valuable because it absorbs more of the sun's heat than ice does and, by transferring it to the ice beneath it, causes melting at a lower temperature and more rapidly than normal.

A moderately coarse to coarse sand is preferable for this purpose. It should be free from clay or silt, since these decrease the efficiency of a sand in melting ice and result in a disagreeable mud after the ice has melted.

Loam *(See molding sand, pp. 125-130)*

Sand for Matches

Ground sand (silica) is used as one of the ingredients of match heads. Medium sized sand is used to form a rough surface on the side of match boxes for striking the matches. Fine sand of about 100-mesh size is also used to coat the sides of the pocket size boxes.

Sand as a Moisture Pad[30]

In order to prevent concrete sidewalks and other like construction from drying too rapidly a clean sand is sometimes spread over the surface in a layer sufficiently thick so that when the sand is wetted periodically it will contain enough water to keep the concrete moist until it has set thoroughly.

Silica or Sand Mold Wash *(See facing sand, p. 113)*

Molding Sand

Molding sands may be divided into two general groups, namely common molding sand, sometimes called foundry sand, and steel molding sand sometimes designated as steel sand. The former is used in making castings requiring a sand which will withstand a moderately high temperature and which is moderately refractory. Common molding sands are also expected, in general, to have a relatively high per cent of natural bond. Steel molding sand must be highly refractory because of the high temperature of the molten steel cast in it, and in general is not required to have a high per cent of natural bond. In fact some steel foundries buy washed sand, preferring to add a predetermined amount of artificial bond such as molasses or flour. In this way a more uniformly bonded sand is secured than when the natural product is used with a bond varying in character and amount. Special names are given to molding sands used in different parts of the operations of molding. The more important of these are as follows:

Core sand—highly refractory sand used for making the cores for molds.

Parting sand—a fine sand consisting preferably of rounded grains used for dusting the meeting faces of molds.

Facing sand—a sand which is generally fine, used to coat the inside of molds in order to give the casting a smooth surface.

Green sand—raw molding sand used in a moist condition.

Dry sand—molding sand which while damp is shaped into molds and then allowed to dry before metal is poured into it.

Loam—a mixture of clay and sand for molding large castings.

Backing or floor sand—this type of sand makes up the bulk of the mold. It gives the mold its strength and offers escape to the gases formed at the contact of the mold and the molten metal.

THE PROPERTIES AND TESTING OF MOLDING SANDS[31]

In view of the great number of different types of molding operations in which sand is used it is obvious that the physical properties of the sands best

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[30] Condra, G. E., The sand and gravel resources and industries of Nebraska: Nebraska Geol. Survey, vol. 3, pt. 1, p. 169, 1908.

[31] A great deal of work has been and is being done on the physical properties of molding sands by the American Foundrymen's Association. For details on the testing of molding sand the reader is referred to the bulletin of that Association for June 1, 1924, or to Illinois State Geol. Survey Bull. 50 in which the specifications for testing are reprinted.

fitted for the various types of work will also be varied. Following is a brief statement of the different physical properties of molding sands and a few specifications showing the character of the St. Peter sand used in molding.

1. Bond strength. The bond strength or cohesiveness of a sand is its ability to stick together and upon this property depends in part the character of the mold a sand will make. Cohesiveness depends principally on the amount, character, and distribution of the bonding material, and the shape, size and character of the surface of the sand grains bonded. Clay and limonite are the bonds most commonly encountered in natural bonded molding sands. It is sometimes desirable to add an artificial bond to a silica sand which is highly refractory but low in bond. Such artificial bonds as flour, molasses or other sugary syrup, gluten, oil of various sorts or fire clay are used. In general an angular sand is said to have greater bonding power than a rounded sand as a result of the strength gained through the interlocking of the grains. The character of the surface of the sand grains composing the molding sand is also of importance inasmuch as frosted grains give a much better opportunity for the adhesion of the bonding material than do smooth surfaced grains. A fine sand has a greater bond strength than a coarse one because the amount of surface tension of the water film between the grains is greater, and the surface for adhesion of the bond is proportionately larger. An even distribution of bonding material is also essential to maximum cohesiveness.

2. Permeability. Permeability is that property of a molding sand which permits the venting of gases evolved at the surface of the mold in contact with the molten metal. Technically, permeability of the crude sands is measured when these sands are tempered with such an amount of water as to give the maximum permeability (optimum water content). Base permeability is the measure of the permeability of the grains of a sand with the bond removed. It is very important in general that a sand should have a permeability sufficient to allow the ready escape of gases, else serious imperfections may result on the surface of the casting. The size of the sand determines in a large measure its permeability. A fine sand is less permeable than a coarse one; also a sand consisting of sand grains of various sizes is not highly permeable because the difference in size permits a tight packing of the grains. A sand composed of rounded sand grains of a given size has greater permeability than an angular sand of the same size, principally because the pore space in rounded sands is more continuous than in angular sands. The amount of bonding material and water present also influences permeability. Both clog the pores of the sand and the maximum working permeability is therefore commonly obtained when the amounts of water and bond are kept at a minimum. The temperature and type of metal to be cast is a fourth factor influencing permeability. Some metals close the pores in the surface of a mold and therefore necessitate the use of highly permeable sands.

3. Texture. The texture of sands is commonly expressed as the per cents by weight retained on a given set of sieves. Texture is a very important property of sand, and bears an important relation to bonding strength and permeability as mentioned under those topics.

4. Durability. The durability of a sand is its ability to withstand repeated using without marked deterioration. This property seems to be dependent principally in the amount and character of the bond present. Detailed data on the rate of deterioration of the various types of sand are not available.

5. Refractoriness. Refractoriness is that property of a sand which enables it to withstand high temperatures without fusing. The refractoriness which a molding sand should possess depends on the sort of metal to be cast. The sand should, of course, have a higher fusion point than the temperature of the molten metal cast in it. Searle[32] gives the following casting temperatures for different metals:

Sand for casting	Maximum temperature attained	
Brass	1350°C.	2462°F.
Iron	1510°C.	2750°F.
Steel	1580°–1650°C.	2876°–3002°F.

The chief factor influencing the refractoriness of molding sands is the impurities present, either in the bond or as grains which may act as fluxes and lower the fusion point of the quartz. Pure quartz will fuse between 1700° (3092°F.) and 1800°C. (3272°F.) Because of the smaller surface area presented in proportion to their volume, large grains of sand take longer to heat than small ones, and, other things being equal, a coarse sand will be more refractory than a fine one. For similar reasons, a rounded sand is more refractory than an angular one under identical conditions.

6. Color. The color of a molding sand is in general unimportant except as it indicates the presence of some colored substance and its approximate amount. Thus a yellow or red sand is probably relatively high in iron oxide content, and a white sand probably contains a much smaller amount of the same sort of material.

7. Chemical composition. The chemical composition of a sand is important, for from it may be determined the amount and chemical character of material other than quartz which is present. In this way the amount and character of fluxing or gas-producing impurities are determinable.

8. Mineralogical composition. Data on the character and amount of the different mineral constituents of a sand may be obtained from a mineralogical examination. This study is of great value as preliminary or supplementary to a chemical analysis.

9. Shape of grains. The shape of the grains composing a sand is an important factor influencing the porosity of the sand and its refractoriness.

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[32] Searle, A. B., Sands and crushed rocks, vol. 2, p. 81, London, 1923.

It is commonly stated that angular sands have a higher bonding strength than rounded sands. For sands using plastic bonds, it is probably true in general that the character of the surface of the grains is as important as the shape of the grains as far as the bonding strength is concerned; that is, a sand whose grains are roughened and to which the bond adheres readily is likely to have a higher bonding strength than a sand composed of smooth grains. The fact that rounded grains are more likely to have a roughened surface than angular grains has been previously mentioned and its bearing here is obvious.

SPECIFICATIONS FOR COMMON MOLDING SAND

It is impossible to lay down any detailed specifications for common molding sands because of the number and complexity of the combinations of properties which may be united in different ways to give equally satisfactory sands for the same or different types of molding. In general, however, it would seem that common molding sand should meet the following requirements:

1. The sand should be free from large lumps or foreign material.
2. The sand should be free from fluxing impurities as constituents of either the sand or the bond, which are active below the maximum temperature to which the sand is to be submitted. Because of its refractoriness, a high content of quartz is desirable.
3. The sand should consist of grains with such a surface and of such size or sizes and shape as to give the necessary permeability and cohesiveness to the sand with the bond used. Further, it is desirable, if possible, to arrange the preceding combination so as to give the casting the finish desired without the use of facing sand.
4. The bond should be as lasting and durable as possible, and present in sufficient quantity to obviate the addition of a further amount of bond to the crude sand.

SPECIFICATIONS FOR STEEL MOLDING SAND AND CORE SAND

The chief requirements for these types of sand are that they be highly refractory and consist of grains of such sizes and shapes as to give the requisite permeability with the bond used. Inasmuch as core sand is often entirely enclosed in molten metal it must be even more refractory than steel sand. For most purposes a grain with a roughened surface is desirable since this property gives the bond a better hold on the grain. A rounded sand is usually preferred. The amount of bond present in the crude sand is not always essential inasmuch as artificial bonds are very commonly used with steel molding sands. The sand, particularly the core sand should, of course, be very low in impurities, especially fluxes, and should be free from hard lumps and foreign substances.

THE ST. PETER SAND AS A MOLDING SAND

The St. Peter sand sold for molding purposes is used primarily as a steel molding and core sand. It is not generally a natural bonded sand and is therefore, not commonly used as molding sand where natural bonded sands are readily available and highly refractory sands are not needed. As a steel molding and core sand the St. Peter is widely used in the middle west. The following specifications give an idea of the character of the sand in commercial use for different types of castings:

Steel molding and core sand for casting car wheels and structural steel

Representative sieve analysis:	*Per cent*
Sand passing through 100 mesh sieve	2.96
Sand passing through 80 mesh sieve	2.75
Sand passing through 60 mesh sieve	8.41
Sand passing through 40 mesh sieve	42.87
Sand passing through 20 mesh sieve	42.6
Sand retained on 20 mesh sieve	.3

Fineness number—35.9

Color—not essential; usually light yellow tinge.

Shape of grains—round grains preferred, to allow for safe void between sand after it is rammed and to insure porosity and permeability.

Chemical analysis—silica content over 96 per cent preferred. Lime should be kept at minimum.

Sand for molding bars, shapes and light rails

Sieve analysis:	*Per cent*
Sand passing 100 mesh sieve	3.2
Sand passing 80 mesh sieve	1.2
Sand passing 60 mesh sieve	6.1
Sand passing 40 mesh sieve	39.3
Sand passing 20 mesh sieve	50.2

Fineness number—33.2

Color—unessential.

Shape of grain—rounded.

Chemical analysis:		*Per cent*
Silica	minimum permissible	98.0
Alumina	maximum permissible	1.0
Magnesia	maximum permissible	.1
Lime	maximum permissible	.5
Iron oxide	maximum permissible	.5

Sand for car couplers

Sieve analysis:

10 per cent must be retained on 20 mesh sieve
30 per cent must be retained on 40 mesh sieve
40 per cent must be retained on 60 mesh sieve
80 per cent must be retained on 80 mesh sieve

Color—prefer sands lacking high color.

Shape of grains—rounded.

Chemical analysis:		*Per cent*
Silica	minimum permissible	97.0
Soda, potash, and lime	maximum permissible	0.4
Total—alumina, magnesia, lime, soda, potash, and iron oxide	maximum permissible	2.0

The following references on steel molding sand contain additional data:

Cole, L. H., Silica in Canada, Part I: Canada Dept. Mines, Mines Branch No. 555, p. 26, 1923.

Condra, G. E., The sand and gravel resources and industries of Nebraska: Nebraska Geol. Survey, vol. 3, pt. 1, pp. 190-191, 1911.

Dake, C. L., The sand and gravel resources of Missouri: Missouri Bur. Geol. and Mines, vol. 15, 2d ser., pp. 73-75, 1918.

Littlefield, M. S., Natural-bonded molding sand resources of Illinois; Illinois State Geol. Survey Bull. 50, 1925.

Ries, H., and Gallup, F. L., Molding sands of Wisconsin: Wisconsin Geol. and Nat. Hist. Survey, vol. 15, pp. 198-259, 1906.

Ries, H., and Rosen, J. A., Foundry sands of Michigan: Michigan Geol. Survey, Ninth Ann. Rept., pp. 41-85, 1908.

Ries, H., and Nevin, C. M., The cohesiveness test for foundry sands: Amer. Foundrymen's Assoc. Reprint No. 374.

Ries, H., The testing of molding sands: Sibley Jour. of Eng., vol. 38, No. 6, June, 1924.

Searle, A. B., Sands and crushed rocks, vol. 2, pp. 75-129, London, 1923.

Teas, L. P., Preliminary report on the sand and gravel deposits of Georgia: Geol. Survey of Georgia Bull. 37, pp. 68-72, 1921.

Mortar Sand

Sand is an important constituent in mortars. The amount of sand used and the specifications for it vary somewhat according to the type of mortar and the use for which it is intended. The following specifications, however, apply in general:

1. General physical properties—the sand shall consist of clean, uncoated grains, and be free from organic material, clay, silt, mica, and shale fragments. Colored sands should generally be avoided.

2. Shape of grains—it is commonly specified that mortar sand should be composed of angular grains; however, inasmuch as angular sand grains do not commonly have a roughened surface it is probable that a rounded grain with a roughened surface could be used with as much advantage as a smooth-surfaced, angular one.

3. Size of grain—the size of the sand used for mortars depends largely on the purpose for which the mortar is intended. The sand should be well graded and in general a fairly coarse sand is used except where the mortar is to be spread very thin; then a finer sand is employed. Sand used for most construction work is commonly finer than 10 mesh, and 90 per cent of it coarser than 100 mesh.

4. Chemical composition—mortar sands should be free from soluble salts inasmuch as these travel to the surface of the mortar as it dries and cause an unsightly scum. Some of the efflorescence seen on brick walls has been caused by the soluble salts which were present in the sand used in the mortar. The salts penetrate the brick and later come to the surface.

The St. Peter sand is a good mortar sand because it is clean and free from soluble salts, consists of grains with a roughened surface, and is produced in well-graded sizes.

Sand for Use in Paint Manufacture

Very finely ground sand, known commercially as air or water floated silica, or bolted silica, is used as a pigment in certain paints, some of which contain as much as 30 per cent of this material. The principal requirements of silica for this purpose are that it be finely ground and white. An angular, sharp-grained silica is preferred because it gives the paint a "tooth". Crushed glassy quartz is said to give a more angular grain in general than the amorphous varieties of silica.[33] Ground silica is also used as a filler in some paints; rounded grains are said to give the paint smoother working qualities.

The St. Peter sand grains are glassy quartz and the ground silica produced from the sand is very satisfactory for use in paints.

PARTING SAND *(See molding sand, pp. 125-130)*

PLACING SAND *(See saggar sand, p. 136)*

SAND FOR PLASTERS

Sand is an important ingredient in all kinds of plasters except certain types, such as plaster of Paris, which are used without the addition of any extraneous material. Plasters may be classified as follows:

(A) Wall plasters
    (1) Gypsum or plaster of Paris plasters
    (2) Lime plasters (either calcium or magnesium limes)
    (3) Portland cement plasters (more exactly mortars)
(B) Floor plasters and hard finish plasters

The amount of sand used in the various plasters mentioned above depends largely on the character of finish and strength desired when the plaster has set. The following specifications will serve to indicate the general requirements which sand for plaster must meet:

Lime plaster:[34] "The sand should preferably be composed of sharp, angular particles, clean and free from vegetable matter, loam, large stones, dust and silt. . . . Tests show that a well-graded coarse sand makes the best mortar."

Gypsum plaster:[35] (a) Sand used for a gypsum plaster shall be free from alkaline, organic and other deleterious substances. All sand must be dry, clean, and sharp.

(b) It shall be graded from fine to coarse, and when dry not more than 10 per cent by weight shall be retained on a No. 8 sieve; not less than 80 per cent by weight shall be retained on a No. 50 sieve, and not more than 6 per cent by weight shall pass a No. 100 sieve. These sieves shall meet the specifications given in the Bureau of Standards' Standard Screen Scale.[36]

Cement plasters:[37]

Sand shall be dry, clean, and sharp, and shall conform as nearly as possible to the following:

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[33] Cole, L. H., Silica in Canada, Part I: Canada Dept. Mines, Mines Branch No. 555, p. 32, 1923.

[34] Lime—The binder in your wall: Nat. Lime Assoc. 1924.

[35] General instructions and specifications for gypsum plasters, The Gypsum Industries, 844 Rush St., Chicago, Ill.

[36] See American Society for Testing Materials Specifications for Gypsum Plastering Sand, Serial Designation C35.

[37] Sweets Architectural Catalogue, 20th ed., p. 363, New York, 1925-1926.

(a) It shall be free from silt and from alkaline, organic, and other deleterious substances.

(b) Not more than 10 per cent shall be retained on a No. 8 sieve.
Not less than 80 per cent shall be retained on a No. 50 sieve.
Not more than 6 per cent shall pass a No. 100 sieve.
Sieves shall meet the specifications of the U. S. Bureau of Standards' Standard Screen Scale.

Because the St. Peter sand is produced well graded, dry, and free from impurities it makes a very suitable plaster sand. It is not an angular sand, however. Wiley,[38] discussing the angularity of sands with reference to the strength of the mortar they make, says: "The usual requirement of specifications that sands for mortar and concrete shall be sharp is not only useless but may even be detrimental and should therefore be omitted. Further, since the condition of the grain surfaces does materially affect the strength of the mortar (the rougher surfaced grains giving the stronger mortar) the specifications should fully cover this point." The frosted surfaces of the grains of the St. Peter sand are therefore probably in part responsible for the satisfactory mortar which this sand produces and its wide use for plastering. Three companies using Illinois St. Peter sand for composition stucco and flooring are using sand which meets the following specifications:

55 per cent passes 20 mesh sieve and is retained on 35 mesh sieve.
38 per cent passes 35 mesh sieve and is retained on 65 mesh sieve.
7 per cent passes 65 mesh sieve and is retained on 115 mesh sieve. The sand must be white.

100 per cent passes 20 mesh sieve and 100 per cent is retained on 120 mesh sieve. The sand must be white; rounded grains are preferred.

100 per cent passes 10 mesh sieve and 95 per cent is retained on 100 mesh sieve.
65 per cent is retained on 48 mesh sieve.
80 per cent is retained on 80 mesh sieve.
The color must be white or light cream; rounded grains are preferred.

One company using Illinois St. Peter sand in the manufacture of finish coat gypsum plasters specify the following:

(a) Finish coat white sand shall be free from salts, alkali, organic or other deleterious substances.

(b) It may be either a native sand or a screened product and when dry not more than 5 per cent by weight shall be retained on the 20-mesh sieve; not less than 70 per cent shall be retained on the 50-mesh sieve; and not more than 10 per cent shall pass through the 100-mesh sieve. The sieves used shall meet the specifications of the Standard Sieve Series as described by the U. S. Bureau of Standards.

(c) The color shall be as nearly white as possible, but shall not be darker than the Standard Ottawa Silica Testing Sand.

SAND FOR PLUGGING OIL WELLS

Most oil wells which are unsuccessful in obtaining oil are plugged or refilled. Sand is used to refill some of these wells. Any available sand is suitable.

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[38] Wiley, C. C., The mortar-making qualities of Illinois sands: Univ. of Illinois Eng. Exp. Station Bull. 70, p. 28, 1913.

POLISHING SAND *(See grinding sand, p. 123)*

SAND FOR USE IN THE MANUFACTURE OF POTTERY

Such products as chemical and electrical porcelain, art pottery, table ware, sanitary ware and floor and wall tiles are included under the name of pottery, and about 35 per cent of finely ground quartz is used in making up the body of the ware. The quartz reduces the shrinkage of the body during drying and gives it rigidity during firing. Sometimes quartz is used to reduce the plasticity of the clay.

A sand which is to be ground for use in the pottery industry should not contain over 0.32 per cent iron and should burn a dead white. According to Cole[39] the material should be ground so that all of it will pass 120 mesh and 90 per cent 150 mesh. The tentative specifications of the American Ceramic Society for silica for whiteware follow:

PROPOSED TENTATIVE SPECIFICATIONS COVERING THE PURCHASE OF PULVERIZED FLINT[40] TO BE USED IN THE MANUFACTURE OF WHITEWARE

1. Sample. In sampling car-load lots, equal amounts should be taken from at least five different points in the car, no two samples being taken within five feet of each other. In sampling from a bin, five separate samples shall be taken from different portions of the bin and not more than two from the same level. The total sample shall not be less than ten pounds.

The samples shall be thoroughly mixed on a smooth surface, divided in halves, one-half spread evenly over the other half. Repeat this operation five times. The mixed sample shall then be quartered and two quarters not adjoining rejected. The remaining quarters shall be mixed as described above, five times, quartered as before and two quarters rejected. The remaining sample shall weigh more than 2.2 pounds (1 kilo.) and shall be placed in a tight receptacle, marked with an identifying number or with the name of the material, car or bin number, and date on which the sample was taken.

2. Chemical composition. The material shall conform to the following limits of chemical composition:

	Per cent
Silica, not less than	99.60
Potash and Soda, not more than	.15
Iron Oxides, not more than	.05
Lime	.10
Magnesia, not more than	.10
Alumina, not more than	.10

3a. Color. The flint when formed into a standard cone and fired in a closed saggar or muffle to a temperature of cone 8 shall have a pure white color both on the surface and the interior and shall be easily broken by the fingers, indicating no fusion.

3b. Fineness of grain. One hundred grams of the sample after being dried to constant weight at 105 degrees C. shall be tested as set forth in paragraph 2b, Feldspar Specifications[41] and the residues on the various standard sieves shall not exceed the maximum totals as set forth in the following table:

STANDARD SIEVE NUMBER

Grade	100	140	200	270	325	*Total residue*
1	0.10	0.2	1.50	2.00	5.0	8.8%
2	0.50	1.0	2.50	3.50	6.5	14.0%

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[39] Cole, L. H., Silica in Canada: Part I, Canada Dept. of Mines, Mines Branch No. 555, p. 31, 1923.

[40] Am. Ceramic Soc. Bull., vol. 2, p. 166, 1923.

[41] Idem, p. 165.

All percentages are calculated on the dry basis.

3c. Moisture content. Unless otherwise specified the purchase price shall be based on the moisture free material and the moisture shall be determined as described under paragraph 3, Feldspar Specifications[41]

3d. Fusion behavior. Test cones shall be made of the material according to standard dimensions, i. e. 2⅞ inches (75 mm.) by 9/16 inch (15 mm.) across the base of one face. An organic bond as dextrine or gum arabic is permissible to insure the cones retaining their form prior to fusion, but such added material must burn out completely and not affect the color of the material. The flint when made into cones as described above shall not deform before cone 24.

3e. Shipping conditions. All material purchased under these specifications shall be shipped in clean closed cars.

4. Rejection. The purchaser reserves the right to reject material which does not conform to the above specifications in every particular and to return rejected material to the vendor for full credit at price charged f. o. b. point of delivery specified by the purchaser.

Those parts of the St. Peter sandstone which are the source of glass sand furnish a supply of raw sand suitable for grinding for use in pottery manufacture. The high purity of the sand makes it particularly well suited. Some of the ground silica produced in Illinois is sold for this purpose.

Poultry and Bird Grit

Small quantities of sand are sold as poultry grit and as grit for pet birds. A coarse sand is desirable for the first purpose and a fine, white sand for the second. No preference is known to exist between round and angular sands for these purposes.

Sand as Railroad Ballast

Some railroads, particularly those which do not have a ready supply of crushed rock or gravel close at hand, use sand as a roadbed base. The sand is placed on the subgrade as a layer about six inches deep and later covered with crushed stone, cinders or gravel.

Sand for use as railroad ballast should be coarse enough to permit ready drainage of water and should not contain clay, silt or organic matter in such amounts as to act as a lubricant when wet and thus cause the sand to slip out from beneath the ties when subject to the weight of traffic. Angular sand may possibly have a slight advantage over rounded sand since the movement of rounded grains on one another would be somewhat easier and greater than the movement of angular grains. The angular grains might therefore remain in position better than rounded grains.

Sand for Railroad Fills

Large amounts of sand are used by railroad companies for making fills and elevating tracks entering and leaving large cities. No specifications of sand for this purpose were noted but it would seem that such sand should be dry when placed, inasmuch as wet sand has a greater volume than dry sand,

and that it should pack well and be free from clay and earth which might later wash out and cause the embankment or fill to settle.

The railroads in the vicinity of Chicago use largely dune and lake sand for this purpose. The St. Peter sand would also doubtless be satisfactory, but the price in general prohibits its use.

SAND FOR REFRACTORY MORTARS AND CEMENTS[42]

Refractory cements and mortars are employed as binders for fire brick and silica-brick used in furnaces, converters, retorts and the like which are to withstand high temperatures. They are also used as a patching material or plaster.

Refractory cements and mortars usually consist of a refractory material such as crushed fire brick, sand or crushed quartzite, held together with a bond of fire clay, ball clay, lime, Portland cement, or sodium silicate.

Sand used for refractory cements and mortars should be fine and highly refractory. It should be clean and free from fluxing impurities. The St. Peter sand is well suited for this purpose.

SAND FOR REFRACTORY WARE

A mixture of fire clay and sand or grog is used for making crucibles, retorts, saggars and the like. Inasmuch as this ware is required to withstand high temperatures, it is desirable that a highly refractory sand, free from fluxing impurities, be used. In general, the sand used is finer than 30 mesh; for retorts and saggars, however, it may be a little coarser. The St. Peter sand is well suited for use in refractory ware.

ROOFING SAND

Roofs, especially those which are flat or nearly flat, are sometimes covered with tar or similar substances and coated with sand. The sand gives them greater weather-resisting properties and in a measure fireproofs them. Sand is also used as a surfacing material for roofing papers.

Roofing sand is in general relatively coarse. The color is usually unimportant. Both rounded and angular grains are used. It is essential that the sand be clean and free from dust so that it may hold well in the mastic.

The St. Peter sand makes a very good roofing sand. One company uses sand from the Ottawa district having the following screen analysis:

Through	*Retained on*	*Per cent*
20 mesh	40 mesh	51.7
40 mesh	60 mesh	28.3
60 mesh	80 mesh	9.1
80 mesh	100 mesh	3.7
100 mesh	200 mesh	5.8
200 mesh		1.4

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[42] Searle, A. B., Refractory materials: their manufacture and uses, p. 379-383, 1917.

Some manufacturers of roofing paper use a finer sand than the above, but in general a sand screening about the same as glass sand is used. (See also sand for tar and roofing paper, p. 141).

SAGGAR OR PLACING SAND[43]

In the manufacture of white ware and tile, a refractory sand is used as a packer in the saggars, or containers in which the ware is burned, and in some cases is placed between the pieces to keep them apart. It is also used for this last purpose with heavy clay products and refractories.

The sand used for white ware and refractories must be clean and low in fluxes and iron. Sand to be used with dark heavy ware need not be so pure. Placing sand is produced in two grades, coarse and fine, testing approximately between 10 and 40 mesh, and 28 and 100 mesh respectively. Both rounded and angular sands are used but the former are preferred since they are not so likely to stick to the ware.

The St. Peter sand makes an excellent saggar or placing sand because it is highly refractory and is produced clean, free from fluxes and well graded in a variety of sizes.

SAND FOR SANDBAGS

Bags filled with sand are used for temporary fortifications in military operations, for temporary dams and levees, and as ballast for ships, balloons, and airships. There are no general specifications for sand for this purpose.

SAND-BLAST SAND

When a jet of sand propelled by a current of air under pressure is allowed to come in contact with a rough object, the impact of each grain produces a small pit or depression. The impact of almost countless grains results in a like number of small depressions causing a gradual wearing away of irregularities and projections and a smoothing and polishing of the surface which the grains are striking. If, however, a very smooth or polished surface is exposed to a sand blast, the formation of innumerable small depressions roughens the surface and produces a dull or frosted appearance. This is essentially the action of a sand blast. The sand feeds from a reservoir into the air supply and the two emerge together from a nozzle which is used to direct the sand against the object being abraded.

Sand blasting is used for a wide variety of purposes some of which are: removing mill scale from hot-rolled sheets and bars; removing furnace scale from forgings after heat treatment; cleaning the paint from steel preparatory to repainting; cleaning stone buildings and dressing stone; cleaning and smoothing castings; giving metal to be enameled or plated a dull, lusterless

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[43] Weigel, Wm., Special sands: U. S. Bur. Mines, Serial 2646, p. 7, Oct., 1924.

but even and uniform surface; producing the ground or frosted surface on glass; and labeling bottles and making decorative frosted designs on glass ware.

Sand-blast sand should be hard, tough, clean, of uniform size and well graded to remove large grains or rubbish which might clog the nozzle of the sand-blast machine. Both angular and rounded grains are used. A steel foundry in Oregon specifies as blast sand a high silica sand, preferably white, of which 39 per cent is retained on 30 mesh, 85 per cent on 40 mesh, 97 per cent on 50 mesh and 99 per cent on 60 mesh. Another large user of sand-blast sand employs a white high silica sand with rounded grains of such size that 96 to 98 per cent will be retained on a 40 mesh sieve.

The St. Peter sand as produced in Illinois is somewhat fine as compared with other sands for sand blasting, but because of its uniform sizes and the natural density and toughness of its grains, it stands up very well as a blast sand and is reported to give superior results.

Sand for Sand Baths

In chemical laboratories containers of hot sand are used to hold vessels which are to be heated gradually and without direct contact with the flame. Sand for this purpose should be free from dust and any impurities which break up or decrepitate on heating. In general a medium sized, high silica sand is preferred.

Sand-clay Roads

As the name suggests, a sand-clay road consists of a mixture of sand and clay. The amount of clay present is generally about that required to fill the voids in the sand. This mixture is effected by combining clay with the sand of a sandy road, by mixing sand with the clay of a clay road, or by surfacing a pre-existing road with a mixture of sand and clay. In the first case mentioned, the control which can be exerted on the quality of the sand in the road is minor. In the last two cases, however, it is possible to specify sand of a certain quality.

In general a rather coarse silica sand free from large amounts of mica is preferred for use in sand-clay roads. According to Baker,[44] "for the best results, not less than 45 per cent nor more than 60 per cent of the sand should be finer than that caught on a standard No. 10 sieve, and coarser than that caught on a No. 60 sieve; and that caught on Nos. 20, 40, and 60 sieves should be about equal to each other."

The St. Peter sandstone in Illinois is in general too fine to pass the above specifications for size. It is, however, a usable sand in other respects.

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[44] Baker, I. O., A treatise on roads and pavements, p. 144, New York, J. Wiley & Sons, 1920.

Sand for Sand Finishing Painted Surfaces

In regions where buildings are subject to sand storms, such as the Pacific coast, sand is used as a finish on painted surfaces to make them resistant to the abrasive effects of the sand of the sand storms. White, sharp, even-grained sand is preferred for this purpose, because the sharp grains hold well in the paint and the angular faces of the grains produce a pleasing glistening effect.[45]

Sand is also used to give a rough effect on painted walls either to prevent writing and scratching on them or to secure a stone-like surface. Such sand should be free from foreign material and impurities but other specifications depend primarily on the effect desired. The St. Peter sand is very suitable for finishing purposes because it is produced in uniform grades and is very clean.

Sand for Sand Finishing Plaster Walls

Sand is applied to plaster walls to secure a sand finish. The size of the sand used and the manner in which it is applied depend on the texture and effect desired. The sand should, however, be even grained and uniform in color.

The St. Peter sand is widely used in the middle west for this purpose because it has an even color and is purchasable well sized.

Sand Paper

At one time sand was used rather commonly as the abrasive surfacing of sand paper. At the present time, however, crushed garnet, quartz, quartzite, or artificial abrasives have largely replaced sand. The abandonment of natural sands in favor of garnet and artificial abrasives has been largely due to the greater angularity and sharpness and the superior hardness of these materials.

Sand for Sand Piles *(See sand for sand tables and sand piles, p. 139)*

Sand for Sand Seals

Sand seals are used in place of water seals where the latter cannot be employed because of the high temperatures to which they would be subjected. Sand seals are used on manhole and flue covers, and dampers of kilns and furnaces and serve to prevent the escape of heat and gases around the edges of the movable parts. The chief requirements of sand for this purpose are that it be highly refractory, fine and preferably round-grained so that the grains may readily roll into and fill any small openings in the seal.

The St. Peter sand is very suitable for sand seals inasmuch as it meets all of the foregoing requirements.

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[45] Condra, G. E., The sand and gravel resources and industries of Nebraska: Nebraska Geol. Survey, vol. 3, pt. 1, p. 201, 1911.

Sand for Sand Tables and Sand Piles

A clean, relatively fine, white sand is used on sand tables and for sand piles in schools and playgrounds. For the former it is desirable that the sand be free from clay; for the latter, however, this is not generally essential but the clay content should be low. The white St. Peter sand would serve excellently for these purposes.

Sawing Sand *(See cutting and sawing sand, p. 111)*

Scouring Sand

Sand is used to some extent as a scouring agent for cleaning metal and other articles. Sand for this purpose is sometimes called "silver" or "livery" sand. The former is generally a white sand; the latter commonly yellow. Very fine sand may also be used as an ingredient of metal polishes.

It is desirable that sand for scouring purposes be fine and evenly graded. Both angular and rounded grains give satisfactory results though the former are probably somewhat more rapid in their action.

Setting Sand

Setting sand is sand used in brick kilns as a cushion on which bricks to be fired are placed. It is also placed between the bricks to prevent their sticking together. Three Illinois brick companies state that they have no strict specifications for the sand. They do require, however, that the sand be free from pebbles and fine enough so as not to indent noticeably the surface of the brick resting on it. The sand also should be capable of standing a heat similar to that used in burning the brick without fusing and should be dry and free from any impurities which might discolor the brick. One of the companies mentioned uses glass sand from Ottawa and finds it very satisfactory because it is dry, white and of a uniform size.

Inasmuch as the St. Peter sand is highly refractory, and is produced well graded and dry, it is used in many places as a setting sand.

Sand for Sidewalks

In the construction of concrete and brick sidewalks the sub-base commonly consists of cinders or gravel. Some of the sub-bases are covered with a cushion of sand on which the brick or cement is laid. Practically any sand which packs well is suitable for this purpose.

Sand for Making Silicon

Silicon is made in an electric furnace by heating sand or quartzite with carbon (coke). The reaction is as follows:

$$SiO_2 + 2C \rightarrow Si + 2CO$$

The sand should be fine and of very high chemical purity.

Sand for Use in Soaps

Ground or fine sand is used as a scouring agent or filler in soaps.

Sand for Making Sodium Silicate (Water Glass)

In the manufacture of sodium silicate, sand in the ground form is used to furnish the silicate portion of the compound. The high chemical purity of the St. Peter sand of the Ottawa district makes it very desirable for this purpose and it is used widely. One company purchases in ground St. Peter sand which meets the following specifications:

2 per cent through 100 mesh (the finer the better)
50 per cent through 50 mesh
90 per cent through 30 mesh

It should be free from dirt and dry. The color of the sand must be white.

The chemical requirements are as follows:

Silica (SiO_2)	Minimum permissible	99.5 per cent
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	Maximum permissible	0.25 per cent
Lime (CaO) and magnesia (MgO)	Maximum permissible	0.0 per cent
Loss on ignition		0.25 per cent

Minimum permissible melting point 1600°C.

Standard Ottawa Sand *(See testing sand, p. 141)*

Sand for Stone-block Pavements

The modern type of stone-block pavement consists most commonly of a concrete base, a sand or mortar cushion and a wearing course of stone blocks. The sand cushion when used is commonly 2 or 3 inches thick. The joints between the stone are filled with cement grout, pea gravel, or sand. The last two materials are commonly mixed with a bituminous mastic such as tar or pitch.

The sand used in the concrete base and cement grout should in general pass the same specifications as given for those parts of the road under Brick Pavements. The sand cushion should consist of clean, fine sand, all of which will pass ¼-inch mesh. The sand used with the tar or pitch filler should be clean and should pass a 20-mesh screen.[46]

Sand for Stucco

The term "stucco" is applied to all forms of exterior plaster work and to certain special types of interior plastering. The exterior stucco is commonly a cement plaster; the interior stucco may be cement, lime or gypsum plaster. In general stucco contains about one part of binder to three parts of sand or other fine aggregate. The specifications of sand for various types of plasters are discussed under the use of sand for plastering (p. 131).

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[46] Baker, I. O., A treatise on roads and pavements, p. 585, New York, J. Wiley & Sons, 1920.

SAND IN SWEEPING COMPOUNDS

Because of its incoherency, sand is used in some sweeping compounds to give them a body which will hold the oil or other dust palliative they contain.

SAND IN TAR AND ROOFING PAPER[47]

In the manufacture of tar paper, sand is used as a coating to prevent the sticking of the paper. Clean, white, dustless sand about 65 mesh in size is commonly used. Ground sand is also sometimes used for this purpose.

SAND FOR TERRAZZO FLOORS

In laying certain types of terrazzo floors it is recommended[48] that a sand bed one-quarter inch thick be laid on a base, that the sand be covered with tar paper and that the latter in turn be covered by a mortar composed of one part Portland cement and four parts of coarse sand. When the mortar has set the terrazzo is laid over it.

SAND FOR TESTING DETONATORS[49]

In testing the efficiency of detonators for explosives a test known as the sand test is sometimes employed. It consists of immersing the detonator in sand and determining the amount of powdered sand produced by firing.

Sand for making this test must be practically pure quartz and all pass 20-mesh sieve and be retained on a 30-mesh sieve. Standard Ottawa sand meets these specifications.

TESTING SAND: STANDARD OTTAWA SAND

Standard Ottawa sand is used for testing the strength of cements and as a laboratory standard in physical tests of other sands. Standard Ottawa sand is very carefully screened so that all the grains pass a 20-mesh sieve but are retained on a 30-mesh sieve.

TUMBLING SAND

Tumbling barrels containing sand used for scouring and polishing small metal articles which are to be plated or lacquered. The size of the sand used in general depends on the character and size of the pieces being cleaned. A sand capable of withstanding wear is essential for this purpose and high silica sands are commonly used.

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[47] Teas, L. P., Preliminary report on the sand and gravel deposits of Georgia; Geol. Survey of Georgia Bull. 37, p. 95, 1921.

[48] Sweets Architectural Catalogue, 20th ed., p. 501, New York, 1925-1926.

[49] Marshall, Arthur, Explosives, 2d ed., vol. 2, p. 530, Philadelphia, 1917.

SAND FOR MAKING WATER GLASS (*See sand for making sodium silicate, p. 140*)

SAND FOR WELDING

Sand, usually finer than 50-mesh, is sprinkled on the surfaces of pieces of iron to be welded and when heated, acts as a flux and forms with the rust or scale on the iron an iron-silica compound which is easily eliminated from the weld by hammering. In this way a good metallic contact is facilitated and the probability of a permanent weld increased. Inasmuch as the silica is the effective agent in this process, a high silica sand is desirable. The St. Peter sand, because it is a high silica sand and fine grained, is a very good welding sand. St. Peter sand sold by one producer in the Utica district gave the following sieve analysis:

Through	*Retained on*	*Per cent*
28 mesh	35 mesh	7
35 mesh	48 mesh	41
48 mesh	65 mesh	20
65 mesh	100 mesh	19
100 mesh	150 mesh	10
150 mesh		3

SAND FOR WOOD-BLOCK PAVEMENTS

The common type of modern wood-block pavement consists of a concrete base, a bedding course of sand, mortar or tar sprinkled with sand, and a wearing course of wood blocks. The joints between the blocks are filled with sand, cement grout, or bitumen. When bitumen is used, the surface of the filled joints is commonly covered with a layer of coarse sand to prevent the bitumen from sticking to passing wheels.

The specifications for the sand used in the various parts of wood-block pavements are in general essentially the same as those for corresponding parts of brick pavements. (See Brick Pavements, p. 107.)

CHAPTER VI.—SAMPLING AND TESTING OF ST. PETER SAND

Value of Tests

Before sampling of the St. Peter sandstone was undertaken, the value of samples was seriously considered. A number of sieve analyses were available, but these were for the most part of certain grades of sand. Such analyses of the crude sand as were obtainable were taken in different fashions by different individuals and were therefore liable to various errors as far as their use for comparative purposes was concerned. It seemed worth while, therefore, from an economic and scientific standpoint, to undertake a sampling campaign of sufficient magnitude to indicate the following: (1) the regional variations in the texture of the sandstone; (2) the magnitude of the local variations in texture, that is within a given quarry or similar unit; (3) the variation in texture in different parts of the same bed; (4) the content and distribution of the yellow iron oxide; (5) the distribution of the clay content; (6) the variations in the different types of crude sand produced. The bearing of the results of the tests on these questions is discussed in Chapter III. Suffice it to say here that the tests on the samples indicate a considerable variation in the texture of the sandstone even in limited areas. Therefore analyses of the sand in any given quarry are not empirically representative of the deposit as a whole. As is true in sampling any variable mineral deposit the samples indicate the character of the sand merely at the places where they were taken.

Sampling the Sandstone

GENERAL STATEMENT

In sampling a sandstone like the St. Peter many problems arise, the chief of which is the availability of the face to be sampled. Most of the quarries have faces 50 feet or more in height which could be sampled only by working from the pile of loose sand which generally is present against the quarry face as the result of blasting operations. Where this loose sand was absent it was rarely possible to sample and generally necessary to wait until after primary blasting had formed the requisite pile. In a number of quarries it was impossible to reach the uppermost beds of sand and therefore these are not represented in the sample. The samples were taken, however, to represent the sand from the entire face insofar as possible.

KINDS OF SAMPLES

According to the purpose of a sample and to the cementation, availability and character of the deposit, five different types of samples were taken.

(1) Face sample. A face sample is one which was taken from a quarry face or an outcrop by first removing any weathered sandstone present and then collecting the sand from a channel a foot wide and an inch deep, extending the entire height of the exposure. As it was generally impossible to sample a quarry face by a single channel, it was often necessary to sample from a series of successively lower, offset channels, each beginning at the same horizon as that at which the channel above it had left off. A chisel pointed hammer was generally used for loosening and cutting down the sand. A large piece of canvas was placed conveniently at the foot of the channel to catch the sand as it fell. Periodically the contents of this canvas were conveyed to the floor of the quarry and transferred to another large piece of canvas on which the sand from the entire cut was collected.

(2) Chip sample. In some exposures the St. Peter was so firmly cemented that it was impracticable to dig a channel. The sandstone was sampled therefore by first removing as far as possible the weathered portion and then taking chips of approximately equal size from the entire height of the exposure. It was thought that the mechanical destruction of the individual grains would be less in samples so taken than in a face sample, because of the pounding of the sandstone necessary to obtain the latter. The chips, like the face sample, were collected on canvases. Before reducing the sample to the size desired for shipment the lumps were thoroughly disintegrated by hitting them with the flat side of a shovel or with a hammer.

(3) Bed sample. The purpose of bed samples was to determine the character of the sand in a given bed. They were taken in the same fashion as the face samples.

(4) Grab sample. In one quarry it was impossible to obtain a sample of the sand from the quarry face because of its precipitousness. A "grab" sample was therefore secured by taking handfuls of sand from various parts of loaded railroad cars. The same number of handfuls was taken from each car.

(5) Plant-run samples. These samples were taken to show how the sand actually produced by a given plant varied from the average analysis shown by the face sample which was taken at about the same time. The plant-run sample was taken directly from the conveyor belt carrying the sand away from the driers.

SPLITTING THE SAMPLE IN THE QUARRY

When assembled on the collecting canvas the face samples weighed between about 200 and 800 pounds; the weight depending on the height of the face sampled. In order to reduce a sample to the requisite 30 or 40 pounds, a sample splitter or riffler of the Jones type was used. The riffler consisted of a galvanized iron frame 12 inches long, 7 inches wide and 8 inches deep, with a total of 6 two-inch openings discharging alternately in opposite directions. The floors of these openings were inclined at an angle of about 45° and formed a sort of chute. The discharge openings of the chutes were 2 by 3 inches. A handle was attached at each end of the riffler and a hook at the middle of the bottom of each end of the frame. In splitting the sample a piece of canvas was fastened to the hooks at the ends of the riffler by means of properly spaced eyelets. The riffler was held by a member of the field party or placed upon a conveniently situated rock. The lumps in the sand on the collecting canvas were crushed and the sand was mixed as thoroughly as possible by shoveling about, and then fed with a shovel 8 inches wide into the riffler. The sand was so fed that the bulk of it fell into the four center openings or chutes. Any sand dropping off the sides of the shovel fell into the two end chutes. By this method the sample was halved or split; one half was caught upon the canvas hooked to the riffler and the other half fell to the ground and was discarded. This process was repeated until the sample was the required size.

The same splitting process was applied to samples other than face samples, which were initially too large for shipment.

SHIPPING THE SAMPLE

The final sample consisted of between 20 and 35 pounds of sand. It was put into a heavy paper bag along with an identification tag. The bag was securely tied and then put into a cement sack which was labeled on the outside for shipment by express. In the course of transit some of the paper sacks broke but the leakage through the cement sacks was very small.

SPLITTING THE SAMPLE IN THE LABORATORY

For purposes of analysis it was necessary to split the field sample to 100 or 200 grams. For this operation an 8-inch tin funnel with a discharge opening of ¼ inch was used. In the small end of the funnel was a metal partition placed so as to exactly divide the discharge opening into two halves. The partition was extended below the funnel to form two chutes discharging in opposite directions. The sand from the chutes was collected in pails. Before the sand was put into the splitter any small lumps remaining in it were crushed by rolling gently with a rolling pin on a board and the sample was thoroughly mixed and screened on a 14-mesh sieve to remove sticks or lumps of pyrite which might clog the discharge of the funnel. Although it took some time to split a sample with this device because of the smallness of the discharge opening, the funnel was large enough to require only occasional refilling and therefore very little attention. In falling from the chutes the sand from some of the samples which contained a high percentage of clay raised small amounts of dust. In splitting sands of this type the pails were covered with pasteboard lids having openings just large enough to accommodate the discharge ends of the chutes.

In order to test the accuracy of this splitter a forty-pound sample was run through it and the two halves weighed. One of the halves weighed two ounces more than the other. It was felt that an error of this size was within the permissible limits of error for splitting a sample. In order to test the splitter further a given sample of sand was run through until about 100 grams was cut down. The same bulk sample was run through the splitter again and another 100-gram sample isolated. Both samples were sieved according to the regular procedure and the results are the two analyses of sample 2 (Table 10). Examination shows these analyses to be very closely similar for the maximum variation between them is only 1.4 per cent. Sample 28 was treated in the same fashion and the two analyses given for it have a maximum variation of 1.7 per cent.

Mechanical Analysis of Samples and Tables of Results

METHODS OF TESTING THE SAND

Only two tests were generally made on the samples of St. Peter sand, namely the fineness or sieve test, and a test for the determination of the amount of clay substance present. Only some of the samples were analyzed to determine their iron content.

In testing for fineness and clay substance the method recommended by the American Foundrymen's Association[1] was followed in a general way. According to these tests a 50-gram sample of thoroughly dried sand is placed in a one-quart jar containing 475 cc. of water and 25 cc. of standard solution of sodium hydroxide and agitated in a mechanical shaker for an hour. After shaking, the sand and water is allowed to stand for ten minutes and the suspended material is siphoned off. More water is added and siphoned off after five minutes. This process is repeated until the water remains clear at the end of the five-minute settling period. The material siphoned off is the clay substance and its quantity is calculated by subtracting the weight of the sand remaining from 50 grams.

In testing the St. Peter samples slight departures were made from the general procedure described above. A sample of about 100 instead of 50 grams was used because it was found that the larger sample gave better results in indicating the amount of the 20-mesh sand and the amount of sand passing the 270-mesh sieve. The sample was not reduced to any standard

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[1] American Foundrymen's Assoc Bull., June 1, 1924. The complete procedure is given in: Littlefield, M. S., Natural-bonded molding sand resources of Illinois: Illinois State Geol. Survey Bull 50, pp. 20-53, 1925.

TABLE 9a.—*Constants for Tyler Standard Screen Scale Sieves*[2]
(Arranged according to sieve openings)

Sieve	Apertures Tyler standard screen scale sieves		Average diameter of product	
	Inches	Millimeters	Inches	Millimeters
1 in.	1.050	26.67	0.896	22.76
¾ in.	0.742	18.85	0.634	16.09
½ in.	0.525	13.33	0.448	11.377
⅜ in.	0.371	9.423	0.317	8.052
3 M	0.263	6.680	0.224	5.690
4 M	0.185	4.699	0.158	4.013
6 M	0.131	3.327	0.112	2.845
8 M	0.093	2.362	0.079	2.014
10 M	0.065	1.666	0.056	1.422
14 M	0.046	1.178	0.0394	1.000
20 M	0.0328	0.833	0.0280	0.711
28 M	0.0232	0.589	0.0198	0.503
35 M	0.0164	0.417	0.0140	0.356
48 M	0.0116	0.295	0.0099	0.252
65 M	0.0082	0.208	0.0070	0.178
100 M	0.0058	0.147	0.0050	0.126
150 M	0.0041	0.104	0.0035	0.089
200 M	0.0029	0.074	0.0022	0.056
270 M	0.0014[a]	0.037		

[a] Assumed.

weight before sieving because it was thought that the sample taken from the splitter after the last reduction was as representative of the whole sample as possible and that the addition or subtraction of any sand would destroy the representativeness of the sample. The extraction of the clay substance was carried out as described above except that about twice the volume of sodium hydroxide solution was used. The clay was saved and caused to flocculate by adding a little concentrated sodium hydroxide solution. The flocculated clay settled rapidly so that it was an easy matter to get rid of most of the water by decantation. The clay was collected on a filter paper and weighed. Inasmuch as the plant-run samples were free from clay as obtained the clay was not calculated as a part of any of the sieve analyses in order that all the sieve analyses might be comparable. In general, no clay determinations were made on samples taken from natural outcrops, because of the possibility that rain wash would probably have removed much of the clay or else introduced it into the sandstone from the overburden and that the analyses would therefore be unreliable so far as the clay is concerned. The sand, freed of clay, was dried and sieved for 15 minutes in a rotap testing sieve shaker. Tyler Standard Screen Scale sieves were used for the sieving. All analyses were made with the same set of sieves, and the results are therefore comparable. Table 9a gives the constants for Tyler Standard Screen Scale Sieves and the average diameter of the product.

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[2] Taggart, A. F., The work of crushing: Am. Inst. Min. Eng. Bull. 85, p. 161, Jan., 1914.
Catalogue 48, W. S. Tyler Co., Cleveland, Ohio, p. 37, 1924.

RESULTS OF MECHANICAL ANALYSIS

Tables 10 and 11 give the results of the sieve tests and the clay determinations. The results in Table 10 are given in per cent by weight; in Table 11 the compositions of the various samples are expressed in per cent by number of grains.

It is of interest to note in connection with the tables that there is rarely accordance between the analyses of the face and plant-run samples from the same quarries. A lack of accordance is rather to be expected since the sand discharging from the drier may represent only a certain part or parts of the quarry face. The plant-run samples were taken to establish this fact and to determine how representative such samples were of the deposit or working face as a whole.

Table 10 includes besides the sieve analysis the fineness modulus. (See pp. 157-158.) The other figures for expressing fineness by a single number can be calculated from the sieve analyses according to the methods described on pages 155-157.

Tests for Angularity

METHOD OF PROCEDURE

In common parlance the St. Peter is generally spoken of as a rounded sand, for the most part correctly so. So far as is known, however, no results have been published comparing the angularity or roundness of the grains of the Illinois St. Peter from different outcrops and horizons in the State; nor are such data available concerning this sandstone in comparison with other sandstones. The specifications for certain uses of sand require that it be angular but the determination of what constitutes an angular sand is left to individual opinion because of lack of definite means of determining and expressing this property. It has seemed worth while, therefore, to consider means for measuring angularity and to suggest a mechanical method for determining it.

Trowbridge and Mortimore[3] recently suggested a method of determining angularity by optical comparison with a more or less arbitrary set of standard angularity grades consisting of representative grains. Sandstone beds have been correlated successfully from well cuttings by this method. However, the procedure involves individual opinion which makes it liable to error. Another method of determining the roundness of sand grains has consisted of rolling them down an incline on to some flat surface and measuring the distance they roll. This procedure, or variations of it, depends for its results principally on the velocity which the grains attain in their descent. Obviously an egg-shaped grain might attain the same velocity as a perfectly spherical grain

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[3] Trowbridge, A. C., and Mortimore, M. E., Correlation of oil sands by sedimentary analysis: Econ. Geology, vol. 20, pp. 409-423, 1925.

TABLE 1(

Sample No.	N	How sold
1.	Ottawa	shed
2.	Ottawa	shed
2.	Ottawa	shed
3.	Ottawa	shed
4.	Ottawa	shed
5.	Ottawa	shed
6.	Ottawa	shed
7.	Ottawa	shed
8.	Ottawa	shed
9.	Standar	shed
10.	Standar	shed
11.	Ottawa	de
12.	U. S. S	shed
13.	U. S. S	shed
13a.	U. S. S	14-inch gnesia bed
14.	Benson-	de
15.	Benson-	de
16.	Benson-	de
17.	Wedron	shed
18.	Wedron	shed
19.	Wedron	shed
20.	Wedron	hed
21.	Wedron	le
22.	Old Mol Twin	
23.	National	le
24.	National	le
25.	Bellrose	le
26.	Illinois	le
27.	Standard	le
28.	Higby-R (Higby	le
28.	Higby-R (Higby	le
29.	Higby-R (Higby	e
30.	Higby-R (Higby	e
31.	Higby-R (Higby	e
32.	Higby-R (Higby	e
33.	Utica F	e
34.	Federal	e
35.	Federal	e
36.	Higby-R (E. J.	hed
37.	Higby-R (E. J.	hed

a Calculated

	Kind of sample	On 20	On 28	On 35	On 48
)..	Face	..	2.2	23.6	35.2
)..	Face	..	1.2	12.0	28.9
...	Face	..	2.8	31.2	36.5
...	Face	.1	2.1	21.0	28.6
...	Face	.05	3.8	27.9	38.8
. 1)	Face	.1	9.3	48.1	27.9
. 1)	Plant run	.3	12.5	43.0	23.6
)...	Face	.2	7.1	36.4	27.9
...	Face	Trace	6.0	38.0	29.8
...	Face	.3	9.3	38.5	25.9
...	Face	.7	13.7	41.0	22.6
35					
....	Face	.0	2.2	19.3	34.7
....	Face	.0	2.6	20.9	30.6
....	Bed	.0	0.3	5.4	21.6
....	Bed	.0	.9	11.7	31.8
....	Plant run	.1	6.0	41.3	31.7
....	Face	..	.8	6.7	27.8
....	Face (Chip)	.1	1.9	8.5	20.2
....	Plant run	..	.4	4.7	16.3
10, uff)	Face (Chip)	..	.6	4.2	16.8
N., ...	Face (Chip)	..	1.5	7.4	19.0
10	Face (Chip)	.1	3.2	16.9	29.7
11	Face (Chip)	.0	1.1	5.8	17.0
10 1)..	Face (Chip)	..	2.7	17.5	34.2
N., ond	Chip	.1	3.1	11.0	22.5
oun	Face (Chip)	..	.7	4.4	23.6
oun	Face (Chip)	..	.4	2.3	13.8
S., one, ...	Face (Chip)	..	..	.3	13.5
N., one)		.1	4.5	10.2	9.2
....		..	.4	3.9	15.2
....		..	.9	10.8	30.0
. 28, long		.2	13.1	30.1	27.3
t. 11		.2	4.3	15.5	25.6
ite).		.0	.3	3.1	15.0
own)		.0	.4	3.5	14.8
N., rper		..	.2	3.7	13.9

stead of 3 sieves (See pp. 157-158).

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5 Idem, p. 215.

—*Continued*

Per cent by weight								Fineness modulus a	How sold
On 65	On 100	On 150	On 200	On 270	Through 270 (Pan)	Total	Clay		
16.5	13.9	4.9	1.9	.8	.8	99.8	1.0	2.53	Crude
20.2	19.6	10.9	4.1	1.5	1.5	99.9	2.3	2.22	Crude
13.4	9.6	3.6	1.6	.6	.6	99.9	1.2	2.65	Crude
14.3	14.6	10.4	5.6	2.0	1.2	99.9	2.8	2.31	Crude
16.7	10.1	1.8	.4	.05	.3	99.9	1.1	2.71	Crude
9.0	4.5	0.6	.2	.1	.2	100.0	1.22	2.93	Washed
11.0	7.6	1.5	.4	.1	.1	100.1	..	2.90	Washed
14.6	10.2	1.9	.7	.5	.6	100.1	1.1	2.74	Crude
15.0	8.1	1.7	.8	.4	.2	100.0	1.7	2.76	Crude
11.6	7.5	3.5	2.0	.8	.6	100.0	1.5	2.75	Crude
10.6	7.2	2.0	1.1	.6	.5	100.0	2.3	2.87	Crude
20.1	17.1	4.0	1.2	.7	.6	99.9	..	2.50	
17.7	17.5	6.2	3.2	.7	.4	99.8	2.6	2.45	Washed
21.3	35.4	9.4	3.4	1.7	1.7	100.2	2.9	2.08	Washed
22.2	23.4	6.3	2.1	.9	.6	99.9	2.05	2.34	Washed
11.8	6.9	1.4	.5	.2	.1	100.0	..	2.83	Washed
28.4	27.5	6.3	1.8	.4	.3	100.0	1.33	2.27	Washed
22.2	37.6	7.9	1.1	.2	.1	99.8	..	2.23	
25.9	43.3	7.8	1.2	.1	.2	99.9	..	2.12	Washed
26.8	38.1	9.8	2.6	.6	.6	100.1	.83	2.08	
23.9	33.6	10.0	3.3	.8	.5	100.0	..	2.14	
26.4	19.5	3.1	.7	.1	.4	100.1	..	2.49	
22.4	36.1	12.4	3.6	.8	.8	100.0	..	2.06	
25.4	16.8	2.4	.5	.1	.3	99.9	..	2.53	
27.8	28.9	5.0	1.1	.2	.2	99.9	..	2.33	
38.4	27.9	4.0	.7	.1	.1	99.9	..	2.24	
33.4	41.2	6.5	1.9	.4	.1	100.0	..	2.08	
39.1	36.3	7.0	2.4	.8	.6	100.0	..	2.02	
3.9	7.4	19.6	28.5	12.5	4.0	99.9	5.5	1.47	
25.5	34.8	11.7	4.5	1.5	2.5	100.0	..	1.96	
24.7	23.6	6.7	1.9	.7	.6	99.9	..	2.31	
18.0	9.7	1.2	.2	.1	.1	100.0	1.34	2.82	
22.4	26.0	5.1	.7	.1	.1	100.0	..	2.44	
27.2	41.3	10.3	1.9	.6	.3	100.0	..	2.05	
26.6	39.8	10.7	2.7	.7	.9	100.1	..	2.03	
29.4	42.8	7.3	2.0	.5	.2	100.0	..	2.07	

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of the same mass if the former rolled on its shortest circumference. Furthermore, unless the sand grains are introduced on to the incline one at a time, there may be interference, crowding, and pushing of the grains which may complicate or partly invalidate the results.

In an endeavor to find some mechanical means of determining relative roundness or angularity which would avoid the foregoing complications, the author has used the following method with considerable success. Sufficient work has not yet been done to make the procedure perfect and many improvements may be made and errors eliminated, but the results seem to justify description of the method at the present time. The method involves a few simple facts which are by no means new, and consists essentially of a means of determining the minimum porosity of sand obtainable by compacting. The most angular grain possible is defined as the grain having the minimum volume and maximum surface area; and conversely the most rounded grain is one having the maximum volume and the minimum surface area.

When perfectly spherical grains of the same diameter are arranged as compactly as possible, that is so that each grain touches twelve other grains, the pore space will be 25.95 per cent.[4] The port space is independent of the diameter of the sand grains provided that they are all the same in a given sample. Further King says of samples compacted by gentle jarring: "For simple sands with angular grains the pore space is much larger than it is for the rounded sands of the same sizes of grains, and in the case of the crushed glass, whose grains are more angular than those of the crushed limestone, which have a tendency to be cuboidal in form, the pore space is the largest of all."[5] It follows then that under conditions of maximum compaction an angular sand of a given uniform size will have a greater porosity than a rounded sand of the same size of grain. It is possible, then, to compare sands as to their angularity or lack of angularity on the basis of their porosity if sand grains of the same size are used and if they can be made to assume their arrangement of minimum porosity similarly by mechanical means.

The apparatus used to produce minimum porosity consisted of a metal tube 1¼ inches in diameter working in two guide sleeves, which was raised about half an inch from below by a plunger operating on an eccentric and allowed to drop. The raising and dropping was repeated at a rate of about 100 times a minute. The cylinder struck on a piece of felt of such thickness as to produce as nearly as possible a "dead" fall, thus reducing to a minimum the amount of rebound imparted to the sand grains in the cylinder and directing the force of the fall towards their downward concentration. The machine was motor driven at a constant speed.

The modus operandi was as follows: About 60 cubic centimeters of sand carefully screened to a given sieve size on a Rotap shaker and dried at 100°

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[4] King, F. H., Principles and conditions of the movements of ground water: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, p. 207, 1899.

[5] Idem, p. 215.

C. was placed in the cylinder, and the machine was started. After a few moments the machine was stopped, a graduated rod was inserted in the cylinder, and the volume of the sand was measured. The machine was then restarted and the operation was continued until the volume of sand in the cylinder could be reduced no further. This volume was taken to represent the volume of the sand grains themselves plus the volume of the voids under conditions of maximum compaction and minimum porosity. The volume of the sand grains was determined by pouring the sand into a funnel with a small discharge aperature which allowed it to run slowly into a graduate partly filled with water, and then noting the amount of water displaced. The small opening of the funnel minimized the likelihood of the inclusion of any large volume of air. The per cent of porosity of the sand was determined as follows:

$$P = \frac{(C - V) \times 100}{C}$$

where

C is the volume of the sand and voids measured in the cylinder

V is the actual volume of the sand grains as calculated from the amount of water displaced in the graduate

P is the per cent porosity, with maximum compaction.

With the apparatus described, tests were run on ten samples of sand, nine of them from the St. Peter and one from the cypress sandstone of Mississippian age, for purposes of comparison. The analyses were run in triplicate and the results were in general sufficiently close to make additional tests unnecessary. Table 12 gives the per cent of porosity as determined by averaging the results of the three tests. The relative angularity figure for the sands has been determined by dividing 25.95, the theoretical minimum porosity for spherical grains, by the porosity of the sample. The nearer the figure is to 1.0, the rounder the sand.

RESULTS OF TESTS

The results of the tests are shown in Table 12:

The table shows that the St. Peter varies areally as to angularity and that the sand of the Ottawa-Utica district is slightly more angular in general than the St. Peter elsewhere in Illinois. The Cypress sand is included simply for contrast and to show the results from artificially crushed and very angular sand. The high angularity shown in the sand retained on the 35-mesh sieve is due to the fact that the grains consisted of aggregates of quartz grains and therefore had a very irregular shape with many re-entrant angles.

As a check on this procedure and its value, photographs were taken of the different grades of sand of six of the above samples. These were submitted to a number of individuals to be arranged in order according to the roundness of the grains. Exact coincidence with the order suggested from the above results was rarely obtained but the average of the judgments seems to justify fully the results described.

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TABLE 12.—*Results of angularity tests*

No. of sample	Name of company	Per cent porosity through 28 on 35	Relative angularity figure	Per cent porosity on 48	Relative angularity figure	Per cent porosity on 65	Relative angularity figure	Per cent porosity on 100	Relative angularity figure
6	Ottawa Silica Company	32.7	.794	34.0	.760	36.4	.714	35.9	.723
8	Ottawa Silica Company	32.3	.804	33.3	.780	34.5	.754	35.4	.734
17	Wedron Silica Company	30.5	.852	32.45	.800	34.1	.761	36.7	.707
26	Bellrose Sand Company	32.7	.794	34.3	.757	34.9	.744	35.0	.742
37	Higby-Reynolds Silica Company (Reynolds east quarry)	33.3	.780	34.2	.759	35.0	.742	35.6	.729
44	Standard Silica Company (Plant No. 1)	32.4	.801	34.2	.759	35.4	.733	36.4	.714
46	Outcrop at Troy Grove	32.7	.794	33.7	.770	36.35	.714	37.45	.693
50	Ballou White Sand Company	31.6	.822	34.4	.755	36.3	.715	37.5	.692
53	National Silica Company	31.1	.835	33.3	.780	34.45	.754	35.55	.730
62	Cypress sand from Cypress, Ill.	45.2	.574	40.0	.649	39.4	.659	40.5	.641
	Average of 9 St. Peter samples	32.1	.809	33.6	.773	35.3	.735	36.2	.717

Tests to Determine the Number of Grains in a Unit Weight of Sand

METHOD OF PROCEDURE

Inasmuch as it is often of interest from an economic and scientific standpoint to know the number of grains of a given size in a particular sample, tests were made to give an approximate idea of the composition of the St. Peter sands by number of grains. These tests consisted of a determination of the average number of grains in a gram of sand of a given size.

From a sample of very carefully washed and sieved sand of a given size a number of grains were counted out and weighed. From this weight the weight of a single grain was calculated and also the number of grains per gram. This was done for the various grades of sand of six different samples selected so as to be geographically representative of the St. Peter. From the average number of grains per gram obtained from these data, the analyses by weight were recalculated to per cent by number and are recorded in Table 11.

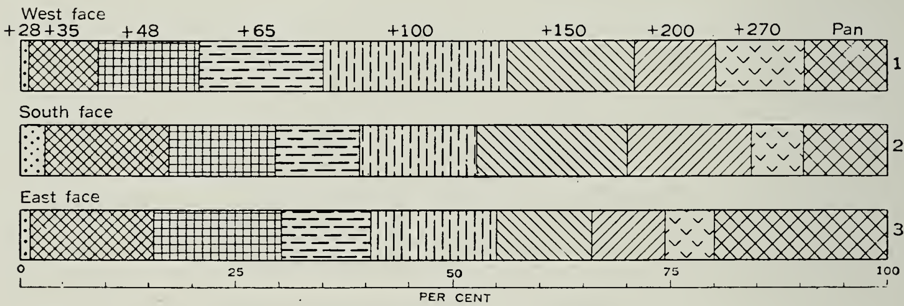

Fig. 41. Graph showing the composition of the samples from the quarry of the Ottawa Silica Company in per cent by number of grains. (Compare with figs. 13 and 14, pp. 43, 44.)

RESULTS OF TESTS

Table 13 shows the results of the experimental work.

Figure 41 shows the percentage composition by number of grains for the face samples taken in different parts of the quarry of the Ottawa Silica Company. Compared with the graphs of figures 13 and 14, the striking difference is in the much larger per cents of the materials below 100 mesh. It is also of interest that the per cents retained on the various sieves show much less variation between maximum and minimum amounts than do the per cents by weight.

In figure 42 the analyses of bed samples in per cent by number of grains are shown for two quarries. The greater similarity of these graphs as compared with graphs based upon the per cent by weight (fig. 12) is worthy of note.

TABLE 13.—*Results of tests to determine the number of grains per gram of sand*

Mesh of sieve	Pan Number of grains counted	U. S. Silica Company No. 12	Higby-Reynolds Silica Company Reynolds east quarry No. 37	Wedron Silica Company No. 17	Ottawa Silica Company No. 8	Standard Silica Company Plant No. 1 No. 44	Bellrose Sand Company No. 25	Average number of grains per gram	Number of grains per gram used for computing per cent by number
+20	50	732	756	740	739	741	759	738	740
+28	100	1,820	1,626	1,660	1,780	1,650	1,805	1,723	1,720
+35	100	3,550	4,258	4,250	3,690	3,450	4,130	3,888	3,900
+48	100	7,940	9,010	8,770	7,930	8,007	8,600	8,376	8,400
+65	200	26,680	30,300	28,180	24,650	22,220	27,020	26,508	26,500
+100	200	71,480	71,450	52,650	51,750	57,150	66,700	61,863	62,000
+150	250	166,600	208,400	208,200	166,600	208,200	208,200	194,367	194,000
+200	250	357,300	416,800	384,600	357,300	333,300	416,600	377,650	378,000
+270	300	800,500	1,000,000	833,800	714,800	625,200	1,000,000	829,050	829,000
	350	1,250,000	1,750,000	1,666,000	1,666,000	1,250,400	1,167,000	1,458,233	1,460,000

Chemical Analyses

In view of the fact that repeated analyses of the St. Peter sand have shown it to contain over 97 per cent of silica in the crude state, and over 99 per cent when washed, no additional analyses were made. Data as to the amount and chemical composition of the clay of the St. Peter and as to the amount of iron present are given in Chapter II. The analyses in Table 14 are typical.

Table 14.—*Chemical analyses of St. Peter sand*[a]

Company	SiO_2	MgO	CaO	Fe_2O_3	Al_2O_3	Total	Authority
Ottawa Silica Company	99.45	Trace	0.13	0.30		99.88	Prof. R. E. Lyons, Indiana University
United States Silica Company	99.89	0.01	0.00	Trace	.051	99.95	R. W. Hunt & Co., Chicago
Wedron Silica Company	99.89	0.01	0.00		.051	99.95	Cary & Moore, Chicago
Higby-Reynolds Silica Company (Reynolds quarry)	99.576	0.002	0.0197	.0903	.283	99.97	Operators of Quarry
Ottawa Silica Company	99.82		0.13	0.05		99.99	Prof. R. E. Lyons, Indiana University

[a] U S. Geol. Survey, Mineral Resources 1911, pt. 2, pp. 624 and 630, 1912.

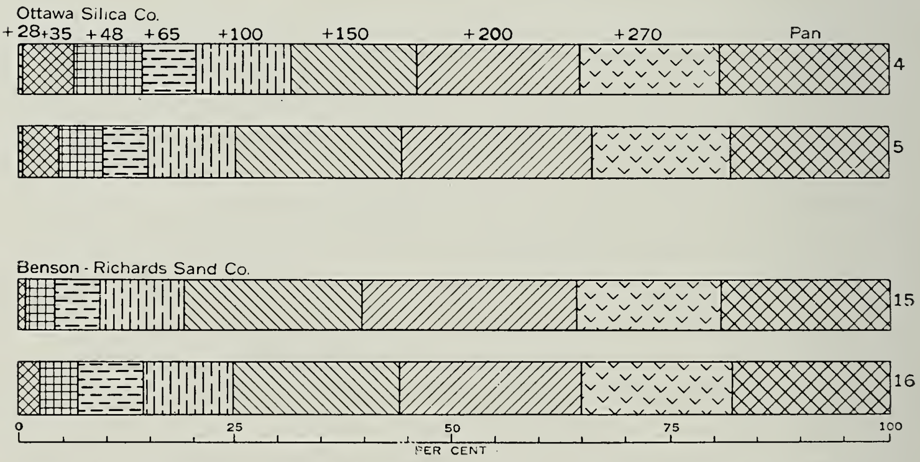

Fig. 42. Graphs showing the analyses by number of grains of bed samples from the quarries of the Ottawa Silica Company and the Benson-Richards Sand Company. Sample numbers are indicated at the right of the graphs.

Modes of Expressing Texture from Mechanical Analyses

EFFECTIVE SIZE

The effective size of a sand is most commonly used with reference to filter sand and is the measure of the opening, expressed in millimeters, which will pass 10 per cent of the average sample of sand. The nearer the effective size is to 1.0 the coarser the sand. The effective sizes of the face samples from the plants producing washed sand are shown in Table 15. Inasmuch as the sand sold as filter sand is usually a screened product this table does not show the character of the prepared sand but does indicate the character of the sand as found in nature and suggests what exposures are likely to furnish the highest per cent of sand suitable for filter sand.

UNIFORMITY COEFFICIENT

The uniformity coefficient of a sample of sand is obtained by dividing the size of opening expressed in millimeters which will just pass 60 per cent of the sand by the effective size. The uniformity coefficient is intended to indicate the uniformity of the sand or the variation in the 50 per cent of sand lying between the finest 10 per cent and the coarsest 40 per cent. The closer the uniformity coefficient is to zero the more uniform the sand.

TABLE 15.—*The effective size and uniformity coefficient of St. Peter sand from quarries of plants producing washed sand*

Sample No.	Company	Effective size	Uniformity coefficient
1	Ottawa Silica Company (plant A, west face)	0.208	2.20
2	Ottawa Silica Company (plant A, south face)	0.295	1.66
3	Ottawa Silica Company (plant A, east face)	0.295	1.70
7	Ottawa Silica Company (plant B)	0.237	2.03
9	Standard Silica Company (plant No. 2)	0.188	2.06
13	United States Silica Company	0.147	2.62
18	Wedron Silica Company	0.167	1.88
36	Higby-Reynolds Silica Company (Reynolds east quarry)	0.167	2.10
43	Standard Silica Company (plant No. 1)	0.255	1.90
47	Ballou White Sand Company	0.138	2.48
51	National Silica Company	0.152	1.82

FINENESS

The difficulty of readily comparing the sieve analyses of different sands because of the number of components making up such analyses has led to the suggestion of various methods of expressing the fineness of a sand by a single figure. Different users of sand have developed different means of arriving at this unit of expression and these methods are described in the following paragraphs.

PER CENT OF FINENESS[6]

The per cent of fineness is determined by adding the per cents of sand passing the sieves of a given set and dividing the number thus obtained by the number of sieves used. The per cent of fineness figures of a number of samples of sand are comparable only if they have been sieved with identical sieves. The following example shows how the per cent of fineness is determined:

Mesh of sieve	Per cent passing
20	99.5
28	94.5
35	59.1
48	29.3
65	15.4
100	5.2
150	2.5
200	1.2
270	0.6
	9)307.3
	34.1 (per cent of fineness)

AVERAGE FINENESS (SCRANTON METHOD)

The International Correspondence Schools of Scranton recommend in their publications on molding sand that the constitution of sands be expressed by the average fineness figure. A set of sieves are used of mesh indicated in the example given below. The fineness figure is determined by multiplying the weight of the sand passing each sieve by the number of mesh of the sieve and dividing the total of all the sieves by 100. The 60-mesh sieve is credited with any loss occurring during the sieving operation and the sand not passing the 20-mesh sieve is credited to a 1-mesh sieve. The following example illustrates this method more concretely:

Mesh of sieve		Weight of sand passing one sieve and retained on the next		
100	x	5.2		520.0
80	x	5.0		400.0
60	x	10.0		600.0
40	x	20.0		800.0
20	x	59.2		1184.0
1	x	0.5		0.5
60	x	0.1	(Loss)	6.0
				100)3510.5
				35.1 Average fineness

The average fineness figure is sometimes spoken of in commercial parlance as the fineness number.

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[6] Kummel, H. B., and Hamilton, S. H., A report upon some molding sands of New Jersey: Geol. Survey of New Jersey Ann. Rept. for 1904, pp. 208-209, 1905.

This method serves as a basis for comparing sand but is open to the objection that it is possible by selecting analyses to obtain the same fineness figure from sands of different sieve analyses.

AVERAGE GRAIN SIZE[7]

The average grain size is a means of expressing the size of the average grain of a sample of sand. It is determined by calculating the average size of each mesh of a sieve of a given number of mesh per linear inch and multiplying it by the amount of sand retained on the given sieve expressed as fractions of unity. The following example illustrates the calculations involved:

Sieve analysis			Calculations for average grain size		
Mesh	Per cent	Fraction of unity		Average screen size[a] Inches	Product of columns 3 and 4
20	8.2	.082	x	.066	.00541
40	43.2	.432	x	.037	.01600
60	24.0	.240	x	.019	.00456
80	12.0	.120	x	.013	.00156
100	10.1	.101	x	.011	.00111
250	1.8	.018	x	.007	.00013
Pan	0.7	.007	x	.002	.00001
	100.0				Total .02878 Average grain size

[a] These average screen sizes are those suggested by Ries and Rosen.

A sand having the average grain size indicated above would pass a 20-mesh sieve (.0328-inch openings) and be retained on a 24-mesh sieve (.0276-inch openings).

The facts that an average screen size must be calculated and that the size of the sand retained on any sieve varies between the sizes of the mesh of the retaining sieve and of the mesh of the sieve through which it passes on to the retaining sieve, are the chief sources of error in this method.

FINENESS MODULUS

The most recent work in determining a single figure which will give the fineness of a sand has been done by Abrams[8] who devised the fineness modulus.

The fineness modulus of an aggregate is defined as the sum of the percentages given by the sieve analysis either by weight or by volume, divided

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[7] Ries, H. and Rosen, J. A., Foundry sands of Michigan: Michigan Geol. Survey Ann. Rept. for 1907, pp. 50-51, 1908.

[8] Abrams, D. A., Design of concrete mixtures: Structural Materials Research Laboratory Lewis Institute Bull. 1, pp. 5-7, Chicago, 1924.

by 100. It is recommended that sieves be used each of which has a clear opening double that of the preceding one. The following example shows how the fineness modulus is calculated:

Mesh of sieve	Per cent retained
28	5.5
48	70.7
100	94.8
200[a]	98.8
	100)269.8
	2.69 Fineness modulus

THE NUMBER OF GRAINS AS A MEASURE OF FINENESS

It may be said in general that the larger the number of grains in 100 grams of sand (Table 11, analyses by number of grains) the finer the sand, and vice versa, by reason of the fact that the finer grains weigh less and therefore are more numerous in a 100-gram sample. Although this method of determining a single figure to represent a sample of sand is open to some inaccuracies, it is probably of as much interest as some of the other methods described and of considerable interest as supplementary to the other figures.

PROPOSED CLASSIFICATION OF ST. PETER SAND ON THE BASIS OF FINENESS MODULUS

Plotting the fineness moduli of the samples of St. Peter sand gives a graph in which three or five size divisions may be delineated. The following classification of the St. Peter is made from the data shown by the graph:

Coarse	fineness moduli 2.76 and larger
Medium	fineness moduli above 2.30 and below 2.76
Fine	fineness moduli 2.30 and smaller

Plotting the moduli of the samples from the washed and crude sand quarries shows the following relations:

Per cent of total number of samples

	Total number of samples	Fine	Medium	Coarse
Crude sand	25	8	56	36
Washed sand	21	14	33	53

The average fineness moduli of the St. Peter sands produced in Illinois are as follows:

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[a] Abrams does not mention the 200 mesh sieve in his work on concrete aggregates, but in view of the fact that the St. Peter. sand is much finer than concrete aggregates it has seemed worth while to include this sieve as a means of yielding more exact data on the sand.

Number of samples		Fineness modules
28	All washed sand	2.60
29	All crude sand	2.63
15	Ottawa district washed sand	2.85
2	Millington district washed sand	2.64
2	Wedron district washed sand	2.27
2	Utica district washed sand	2.29
2	Oregon district washed sand	2.20

GRAPHIC METHODS OF REPRESENTING SIEVE ANALYSES

Sieve analyses may be represented graphically in a number of ways. These, however, may be generally combined into two groups: (1) That consisting of a number of patterns whose total length or area represents 100 per cent and whose individual length or area equals the per cent of sand retained on a given sieve. (2) That consisting of a curve plotted on rectangular coordinates. The vertical axis of the graph is commonly the per cents of sand retained and the horizontal axis the sizes of the sieve openings in inches or millimeters. These sizes of sieve openings may be plotted as arithmetical differences or as the logarithms of the openings. In the former case the spaces on the horizontal axis of the graph become progressively smaller as the finer sieves are reached; in the latter case all sieve sizes are equally spaced. Figure 43 shows several ways of representing the following sieve analysis:

Sieve	Per cent retained	Cumulative per cent retained
20	2.0	2.0
28	8.3	10.3
35	42.0	52.3
48	26.1	78.4
65	9.4	87.8
100	7.8	95.6
150	2.3	97.9
200	1.0	98.9
270	0.5	99.5
Pan	0.5	....
	100.0	

Each of the diagrams shown in figure 43 has features which are in its favor. Some of the outstanding ones may be mentioned briefly. The cumulative diagrams, both logarithmic (A) and direct (B), permit the calculation of the amount of sand retained on any given sieve, whether in the set used for the analysis or not, by interpolation. From this type of diagram the effective size and uniformity coefficient are also readily calculated. To one familiar with sieve analyses represented in this fashion the cumulative diagrams are very satisfactory. They lack, however, the more evident proportional division of the sizes of the sands and percentages of each shown in the other diagrams. Block diagrams C and D are similar; the chief difference is that D requires less space and a larger number of diagrams for comparison can be drawn in a given space. Block diagram E permits of a direct reading

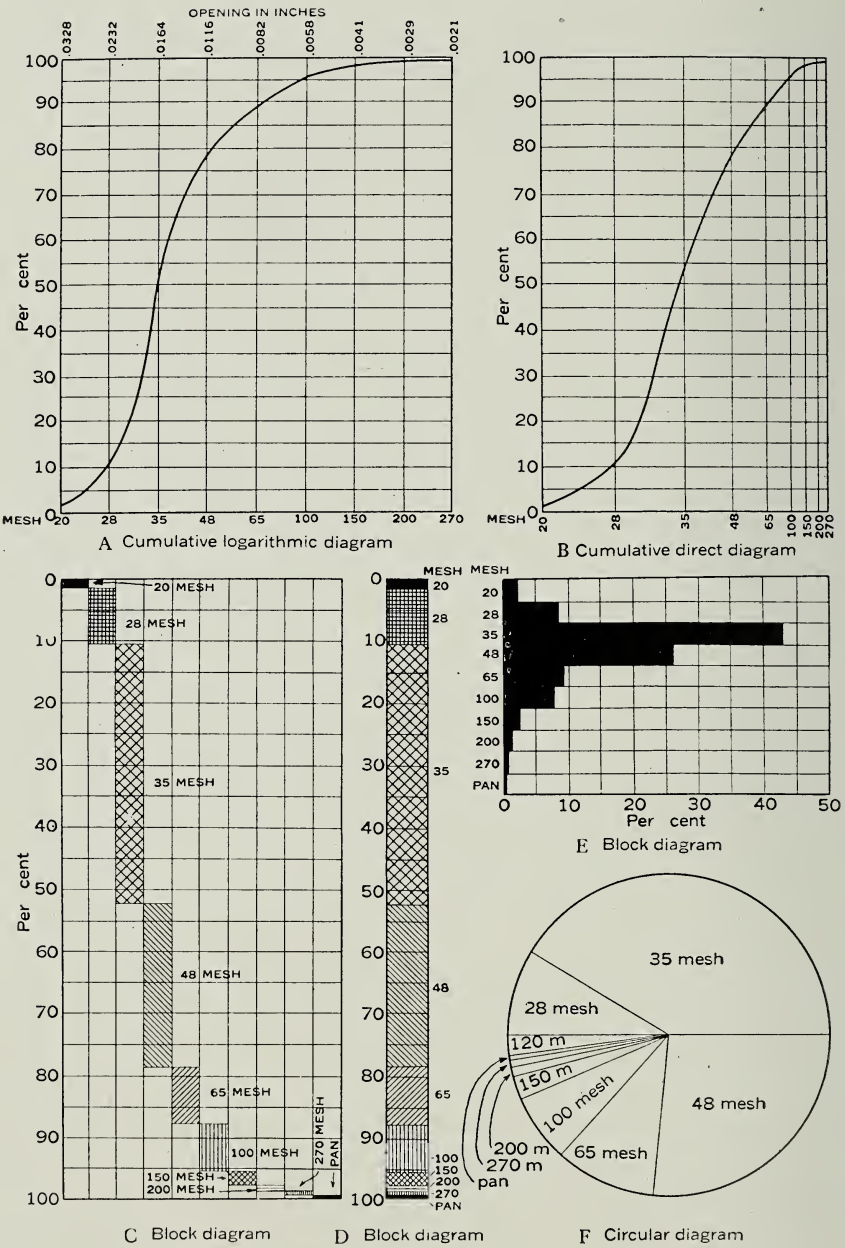

Fig. 43. Graphic methods of representing sieve analyses.

of the various per cents of the component parts of an analysis but does not show the relation of the component parts to the entire sample or 100 per cent as readily as do C and D. It also requires more space than does D and is therefore somewhat less suited for visual comparison. Furthermore it is difficult to catch the difference between two adjacent bars readily, especially if the diagram is rather small. Circular diagram F shows very readily the relation of the various components of a sieve analysis to the total sample of sand but is space consuming and not particularly suited to visual comparison of a large number of analyses.

CHAPTER VII—UNDEVELOPED DEPOSITS OF ST. PETER SANDSTONE OF POTENTIAL COMMERCIAL VALUE

INTRODUCTION

Considering the age and state of development of the St. Peter sand industry of Illinois, it is obvious that the best sites for commercial operations are being developed or held as reserve for future development. Any new site to be capable of commercial exploitation must be one from which sand can be produced at a price competitive with current prices of sand of similar grade and character already in the market. Whether sand can be produced at a competitive price from a given deposit depends on a number of variable factors, some of which are:—the character of the sand; natural advantages which make quarrying easy; the amount and character of the overburden and the ease with which it can be moved and disposed of; the skill exercised in quarrying; the efficiency of the quarrying and sand-preparing equipment; the length of the haul from the quarry to the railroad cars; switching charges to trunk railroad lines; labor costs and supply; and the volume of sand which can be marketed. Thus at times of low prices some quarries may not be able to produce sand at a profit whereas higher prices may make profitable production possible for the same quarries.

In view of the many variables involved in the determination of what a commercially valuable deposit of St. Peter sandstone is, it is proposed to indicate areas, rather than specific sites, where such deposits may occur, with any pertinent data available concerning the character of the sandstone, for the guidance of those interested. Reference should also be made to Chapter II for details of the distribution and character of the St. Peter at the outcrops mentioned. Some of the deposits mentioned are probably not commercially available at the present time because of their distance from a railroad, but are potentially valuable as a future source of supply.

THE ROCK TERRACE OF ILLINOIS RIVER IN THE VICINITY OF OTTAWA

The rock terrace in the valley of Illinois River is the site of a number of washed sand quarries and most of the available acreage close to transportation either is not on the market, or is a part of the city of Ottawa. However, in the SW. ¼ sec. 21 and S. ½ sec. 20, T. 33 N., R. 3 E., there is a tract probably underlain by St. Peter sandstone at a shallow depth in places at least. The sandstone outcrops in the NW. ¼ SW. ¼ sec. 21 in some abandoned quarries. In the vicinities of these old quarries the overburden is largely black loam. Elsewhere it is probably sand and gravel, which may possibly be worked together with the underlying sandstone. The St. Peter sand is probably of the same general character as in the vicinity of Ottawa. The chief handicap of this site is the lack of transportation close by. The nearest railroad connection is the switch of the South Ottawa Silica Sand Company about two miles northeast.

Buffalo Rock

There are already a number of quarries in the northwest side of Buffalo Rock. The east end of the Rock is the site of a sanitarium, but the south and a part of the southeast sides of the Rock are not at present being quarried. Some abandoned pits occur in the last mentioned tract, but there is still a possibility of further development. The overburden is similar to that at the quarries of the Benson-Richards Sand Company, Ottawa Silica Molding Sand Company, and Buffalo Rock Silica Company which are located in Buffalo Rock. The sand from Buffalo Rock above the level of the floor of Illinois Valley is probably much the same as that in the quarries just mentioned.

There is a possibility that on the west end of Buffalo Rock the sandstone may extend as a sort of shelf for some distance west from the foot of the Rock under a cover of sand and gravel capable of commercial exploitation and that the sandstone is of such purity as to be good glass sand.

Transportation at Buffalo Rock could be furnished by the Illinois Traction System.

The North Bluff of Illinois River from Ottawa to Utica

The North bluff of Illinois River between Ottawa and Utica is the site of the majority of the crude sand quarries in the Ottawa-Utica district. However, a number of available sites still remain in this bluff area. The principal problem connected with the development of these sites is the removal and disposal of the overburden. As has been previously stated, east of the Higby Ravine the overburden is Pennsylvanian shale, clay and coal and some glacial drift; west of Higby Ravine it is principally glacial drift. The character of the sand in this bluff and the quarries already operating are described elsewhere in this bulletin.

The Illinois River Bluff West of Utica

West of Utica the Illinois River bluff is made up principally of Shakopee dolomite with a capping of St. Peter sandstone. The best site for a quarry is probably about an eighth of a mile northeast of Split Rock in sec. 13, T. 33 N., R. 1 E., where the steeply dipping beds of the St. Peter underlie a belt about an eighth of a mile wide. Back from the bluff the area widens to half a mile or more.[1] The overburden is glacial drift. The sand is probably much like that near Utica.

The South Bluff of Illinois River

From Ottawa west to Covel Creek the south bluff of Illinois River is composed of Pennsylvanian beds. West of Covel Creek, however, the St. Peter rises in the bluffs and forms prominent cliffs, but the major portion of this area is included in Starved Rock State Park, and is therefore not available for commercial exploitation. The portion between the east edge of the park and Covel Creek has too much overburden to be of commercial value except for mining.

West of Starved Rock State Park in secs. 19 and 20 T. 33 N., R. 2 E., is a strip about a fourth to a third of a mile wide along the bluff with only a moderate cover, which might be commercially exploited. The lack of transportation is the chief handicap of this site. It is about a mile and a quarter north across Illinois River to the Chicago, Rock Island and Pacific Railway and the Illinois Valley Electric Railroad.

Vermilion River

The outcrops of St. Peter along Vermilion River are not extensive. The overburden is glacial drift with or without Pennsylvanian beds, or Platteville-Galena limestone. Transportation is not conveniently near. The outcrops are in general rather low and it is probable that the level of ground water in the sandstone would prevent very deep quarrying.

Pecumsaugan Creek

In sec. 6, T. 33 N., R. 2 E., a belt about a half mile wide along the west bank of Pecumsaugan Creek is underlain by St. Peter sandstone with a moderate cover. This site is handicapped by the lack of convenient transportation.

Clark Run

Along the valley of Clark Run near Utica there may be sites where the overburden of glacial drift is thin enough to permit the development of a quarry. This is true in limited areas but detailed test drilling is necessary to determine the extent of such a condition. A gravity system for running cars from the quarry to the railroad at Utica could perhaps be effected. The sand is probably like that in the Illinois bluff near Utica.

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[1] Cady, G. H., Geology and mineral resources of the Hennepin and La Salle quadrangles: Illinois State Geol. Survey Bull. 37, Pl. I, 1919.

Fox River

The outcrops of St. Peter along Fox River are limited principally to the rock terrace in the valley bottom. At the edge of this terrace away from the river the overburden consists of Pennsylvanian strata and in general is too heavy to be moved. In places, however, the rock terrace is wide enough to permit a sizable quarry. The overburden is principally river alluvium, and is commonly 3 to 6 feet thick. The broadest parts of the rock terrace or of the Fox valley flats are in secs. 3 and 21, T. 34 N., R. 4 E.

Test drilling is advised to determine the general character of the overburden and St. Peter surface in this area. Inasmuch as the terrace was once the bed of Fox River its surface is probably uneven. The Chicago, Burlington and Quincy Railroad is located along the west side of the valley.

In the vicinity of Millington it is possible that detailed search may reveal additional quarry sites. The Chicago, Burlington and Quincy Railroad is on the east side of the river.

The Oregon-Dixon Area

There are many good sites for quarries in this area but they lack transportation facilities. The country is for the most part dissected and quarries located at some distance from a railroad are therefore not generally feasible. The best sites are between the quarry of the National Silica Company in the center of sec. 8, T. 23 N., R. 10 E., and the flat of Gale Creek about a mile east, and the isolated hill in the E. ½ sec. 10, of the same township. Both of these sites are on the Chicago, Burlington and Quincy Railroad.

The first site will require considerable exploratory work to determine the best location for the quarry. The overburden is glacial drift of variable thickness but is in general thin. The rock surface is uneven.

The second site faces Rock River on the west and is practically free from overburden on that side. An 80-foot face of sand is exposed. The sand is very yellow and streaked with iron in the upper 25 feet. Below this it is less yellow and freer from iron. The thickness of the overburden is difficult to determine because the hill is wooded, but it is probably between 5 and 10 feet. Sample 54 was taken from the exposure along the river.

Samples 55, 56, 57, 58 and 66 whose locations are given in the table of fineness tests (Table 10) were taken in the Oregon-Dixon area to indicate the general character of the sand in that area. A brief description of the locations where the samples were obtained follows:

Sample 55—railroad cut in ridge.

Sample 56—32 foot exposure of upper St. Peter. The sandstone is yellow and contains irregular iron bands. Locally a 3-foot cross-bedded layer is present. Many grains of sand are angular probably as a result of secondary growth.

Sample 57—60 foot exposure of St. Peter. Some of the beds especially near the top of the exposure are of remarkably even grain. In general the beds are thick but near the top of the outcrop ½ to 2-inch beds are common. The sandstone is not notably stained by iron.

Sample 58—30 foot exposure of sandstone in road cut. The sandstone is in general yellow, especially in zones 12 to 24 inches thick. Bedding is moderately well developed.

Sample 66—30 foot of St. Peter in road cut; probably lower St. Peter. In general the bedding is not distinct. Iron is present as yellow horizontal bands.

Brookville-Harper Area

Detailed work in the Brookville-Harper area in Ogle County will probably reveal suitable sites for new quarries. The country is rolling and consists largely of long low ridges 30 to 60 feet high, most of which probably have a core of St. Peter sandstone. The overburden consists principally of 2 to 5 feet of loess, underlain by 1 foot to 15 feet of glacial drift. Locally limestone may rest on the sandstone below the glacial drift. The exposures of the St. Peter are in general limited to a few feet of sandstone which is badly yellowed by iron. No railroad is convenient to the general area of outcrop. Sample 70 comes from an 11-foot exposure of sandstone along a road.

Calhoun County

The outcrop of St. Peter sandstone along Mississippi River in Calhoun County between Dogtown and West Point landings is capable of development only so as to employ water transportation. There are no railroad facilities. Near Dogtown Landing the overburden is loess from 20 to 40 feet thick. Further north the Joachim limestone rests on the sandstone. A bluff of about 80 feet of sandstone is exposed as a nearly sheer cliff along the river. The character of the sandstone is described in Chapter II. Sample 60 comes from the top 28 feet and sample 61 from the 26 feet of sandstone below this. It is likely that detailed exploratory work will reveal locations where the overburden is sufficiently thin and easy to remove to make a suitable quarry site. As previously mentioned, the sand contains calcareous material locally and is ferruginous on weathered exposures.

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